U.S. DEPARTMENT OF COMMERCE
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PB-271 753

Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development Volume II. Detailed Analyses and Supporting Materials

Oklahoma Univ., Norman

Prepared for

Environmental Protection Agency, Washington, D.C.

Jun 77

PA

PB 271 753

d States
nmental
tion Agency

Office of
Research and
Development

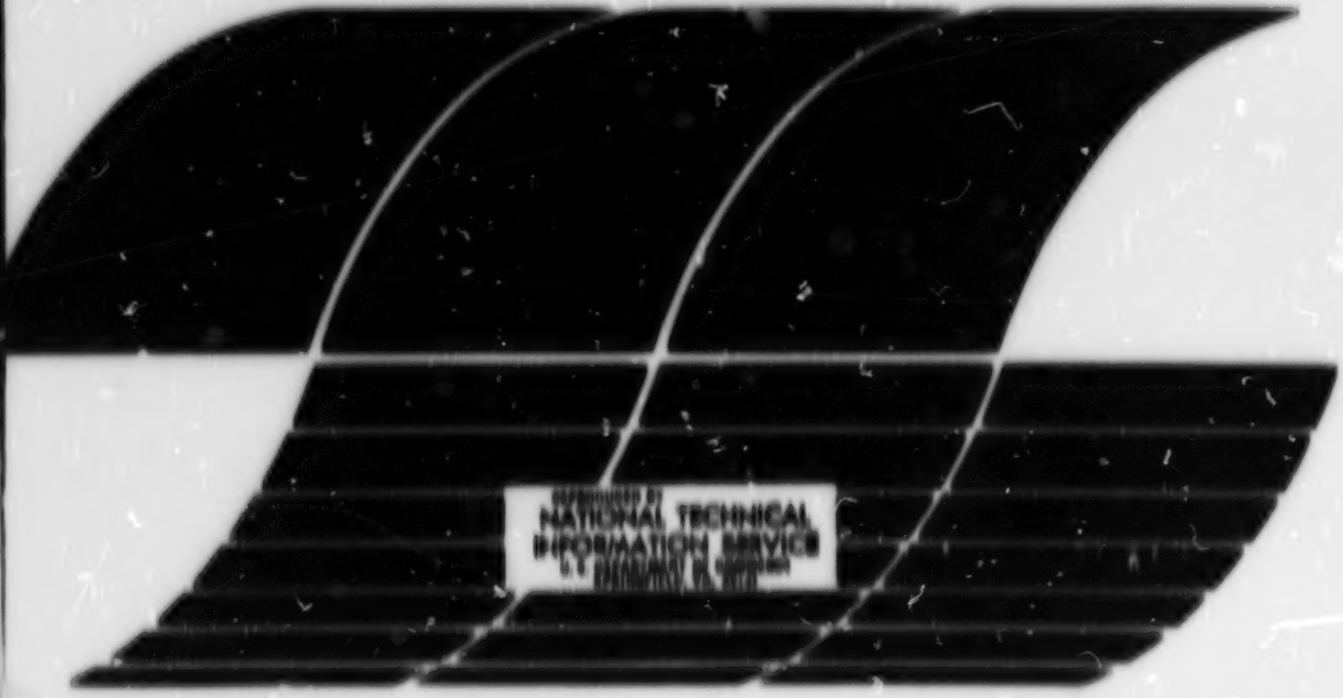
Energy,
Minerals and
Industry

EPA-600/7-77-072b

July 1977

ENERGY FROM THE WEST: A PROGRESS REPORT OF A TECHNOLOGY ASSESSMENT OF WESTERN ENERGY RESOURCE DEVELOPMENT
VOLUME II

Interagency
Energy-Environment
Research and Development
Program Report



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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/7-77-072b

2.

3. RECIPIENT'S ACCESSION NO.
PB 271 753

4. TITLE AND SUBTITLE
Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development Volume II Detailed Analyses and Supporting Materials

5. REPORT DATE
June, 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Science and Public Policy Program
University of Oklahoma
601 Elm Avenue, Room 432
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10. PROGRAM ELEMENT NO.
EHE 624C

11. CONTRACT/GRANT NO.
68-01-1916

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Research and Development
Office of Energy, Minerals, and Industry
Washington, D.C. 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final, July, 1975-March, 1977

14. SPONSORING AGENCY CODE
600/17

15. SUPPLEMENTARY NOTES
This project is part of the EPA-planned and coordinated Federal Interagency Energy/Environment R&D Program

16. ABSTRACT

This is a progress report of a three year technology assessment of the development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium) in eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) during the period from the present to the year 2000. Volume I describes the purpose and conduct of the study, summarizes the results of the analyses conducted during the first year, and outlines plans for the remainder of the project. In Volume II, more detailed analytical results are presented. Six chapters report on the analysis of the likely impacts of deploying typical energy resource development technologies at sites representative of the kinds of conditions likely to be encountered in the eight-state study area. A seventh chapter focuses on the impacts likely to occur if wester energy resources are developed at three different levels from the present to the year 2000. The two chapters in Volume III describe the political and institutional context of policymaking for western energy resource development and present a more detailed discussion of selected problems and issues. The Fourth Volume presents two appendices, on air quality modeling and energy transportation costs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Systems Analysis	Technology Assessment	0402	1001
Electrical Power		0503	1002
Fossil Fuels		0504	1202
Ecology	Western Energy	0511	1302
Government Policies	Resource Development	0606	1401
		0701	2104
	Secondary Impacts	0809	

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 842
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PC $21.25 MF A01

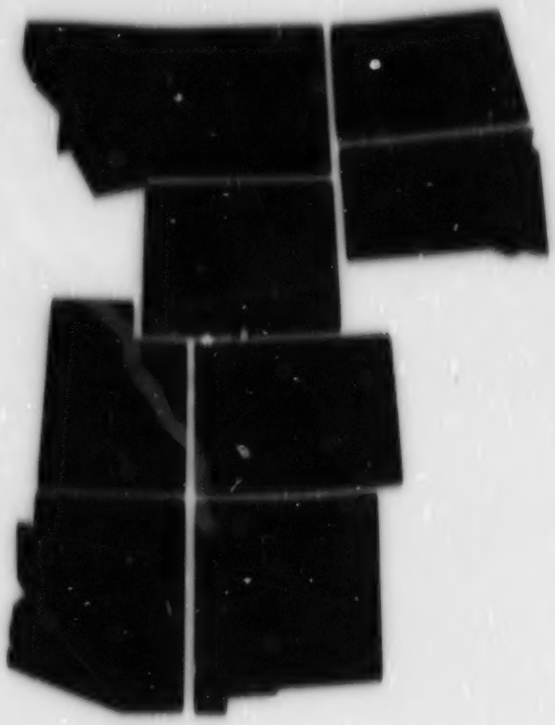
EPA Form 2220-1 (9-73)

☆U.S. GOVERNMENT PRINTING OFFICE: 1977-281-587/43

Energy from the West

A Progress Report of a Technology Assessment of Western Energy Resource Development

Volume II
Detailed Analyses and Supporting Materials



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Contract Number 68-01-1916

Prepared for:
Office of Research and Development
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Washington, D.C. 20460

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DISCLAIMER

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FOREWORD

The production of electricity and fossil fuels inevitably creates adverse impacts on Man and his environment. The nature of these impacts must be thoroughly understood if balanced judgements concerning future energy development in the United States are to be made. The Office of Energy, Minerals and Industry (OEMI), in its role as coordinator of the Federal Energy/Environment Research and Development Program, is responsible for producing the information on health and ecological effects - and methods for mitigating the adverse effects - that is critical to developing the Nation's environmental and energy policy. OEMI's Integrated Assessment Program combines the results of research projects within the Energy/Environment Program with research on the socioeconomic and political/institutional aspects of energy development, and conducts policy - oriented studies to identify the tradeoffs among alternative energy technologies, development patterns, and impact mitigation measures.

The Integrated Assessment Program has utilized the methodology of Technology Assessment (TA) in fulfilling its mission. The Program is currently sponsoring a number of TA's which explore the impact of future energy development on both a nationwide and a regional scale. For instance, the Program is conducting national assessments of future development of the electric utility industry and of advanced coal technologies (such as fluidized bed combustion). Also, the Program is conducting assessments concerned with multiple-resource development in three "energy resource areas":

- o Western coal states
- o Lower Ohio River Basin
- o Appalachia

This report describes the results of the first phase of the Western assessment. This phase assessed the impacts associated with three levels of energy development in the West. The concluding phase of the assessment will attempt to identify and evaluate ways of mitigating the adverse impacts and enhancing the benefits of future development.

The report is divided into an executive summary and four volumes:

- I Summary Report
- II Detailed Analyses and Supporting Materials
- III Preliminary Policy Analysis
- IV Appendices

Stephen J. Gage
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for Energy, Minerals, and Industry

ABSTRACT

This is a progress report of a three year technology assessment of the development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium) in eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) during the period from the present to the year 2000. Volume I describes the purpose and conduct of the study, summarizes the results of the analyses conducted during the first year, and outlines plans for the remainder of the project. In Volume II, more detailed analytical results are presented. Six chapters report on the analysis of the likely impacts of deploying typical energy resource development technologies at sites representative of the kinds of conditions likely to be encountered in the eight-state study area. A seventh chapter focuses on the impacts likely to occur if western energy resources are developed at three different levels from the present to the year 2000. The two chapters in Volume III describe the political and institutional context of policymaking for western energy resource development and present a more detailed discussion of selected problems and issues. The Fourth Volume presents two appendices, on air quality modeling and energy transportation costs.

READER'S GUIDE

This report is divided into four volumes. In addition, an executive summary provides a brief description of the major research results of this western assessment.

Readers interested in a general description of the assessment results should read Volume I. Chapters I and II describe the context and methodological framework of the assessment. Chapter 3 provides a summary description of the impact analysis, e.g., water and air impacts, population changes, etc. Chapter 4 summarizes some policy implications of these results, although the assessment is still in the early stages of policy analysis at this time. Chapter 5 briefly describes what the reader can expect from the second phase of the project.

Readers interested in particular geographical areas might be interested in one or more of the six site-specific chapters (Chapters 6-11) of Volume II which describe in detail results pertaining to the following areas: Kaiparowits/Escalante, Utah; Navajo/Farmington, New Mexico; Rifle, Colorado; Gillette, Wyoming; Colstrip, Montana; and Beulah, North Dakota. Readers interested in site-specific air, water, socio-economic and ecological impacts will find these discussed in subsections 2, 3, 4, and 5, respectively, of each chapter in this volume. Chapter 12 in volume II describes the results of the regional analyses. This chapter should be particularly valuable to readers interested in transportation, health, noise and aesthetic impacts, which are not discussed in the site-specific chapters, and subjects (such as water availability) which tend to be regional rather than site-specific in nature.

Volume III represents a first step in the identification, evaluation and comparison of alternative policies and implementation strategies. Chapter 13 presents a general overview of the energy policy system. Chapter 14 identifies and defines some of the principal problems and issues that public policymakers will probably be called on to resolve. The categories of problems and issues discussed are: water availability and quality, reclamation, air quality, growth management, housing, community facilities and services, and Indians.

Volume IV provides two technical appendices:

- a discussion of alternative approaches to modeling air quality in areas with complex terrain
- cost comparisons of unit trains, slurry pipelines and EHV transmission lines

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PART II

DETAILED ANALYSES AND SUPPORTING MATERIALS

INTRODUCTION

In this part of the draft first year progress report, the detailed impact analyses and a more extended discussion of selected problems and issues are presented. Both have been described in Part I and the results of the impact analyses and discussion of problems and issues have been summarized in Chapters 3 and 4.

Impact Analyses

The results of the detailed impact analyses are reported in Chapters 6 through 12. As described briefly in Chapter 3 and in detail in the *First Year Work Plan for a Technology Assessment of Western Energy Resource Development*,[1] seven scenarios postulating hypothetical patterns of energy development in the western U.S. were used to structure the impact analyses described in this report. These seven scenarios were constructed to provide a vehicle for analyzing a broad range of impacts and policies and a basis for the formulation of generalizations about the consequences of various patterns, rates, and levels of development of western energy resources.[2] Six of seven scenarios postulate the development of one or more energy resources at specific sites using specified combinations of technological alternatives. The seventh covers the eight-state study area made up of Arizona, Colorado, Montana, New Mexico, North and South Dakota, Utah, and Wyoming.

Chapters 6 through 12 report the results of the site-specific and regional impact analyses. Each of these chapters focuses on a single scenario and begins with an overview description of the hypothetical energy development specified in the scenario and the conditions existing at the site or within the area where the hypothetical development is to take place. Each development is assumed to produce a beneficial energy output. Both positive and negative impacts likely to result from this development are identified, described, and analyzed.

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[1] White, Irvin L., et al. *First Year Work Plan for a Technology Assessment of Western Energy Resource Development*. Washington: U.S., Environmental Protection Agency, 1976.

[2] Six resources are included in the study: coal, oil shale, oil, natural gas, uranium, and geothermal.

The categories used in analyzing site-specific impacts are air, water, ecological, and social, economic, and political. In addition, transportation, noise, health effects, aesthetics, energy, personnel resources, and materials and equipment impacts are analyzed in the regional scenario. In several of these categories, both positive and negative impacts can be identified. However, by their very nature, some categories (such as air quality) focus primarily on negative impacts.

Although separated for purposes of analysis, impact categories obviously interact with and thus affect one another. For example, population increases may generate increased air emissions which in turn may affect health and the delivery of health services. When appropriate, the analyses reported in the following chapters attempt to take these interactive relationships into account by introducing an impact from one category into the analysis of another category of impacts. (However, as mentioned earlier, there has not been adequate time for this to be done systematically during the first year.) In a final section in each chapter, impacts are summarized, and selected technological alternatives which would enhance, mitigate, or eliminate some of these impacts are discussed.

During the first year technology assessment (TA), emphasis was placed on structuring the various impact analyses, insuring that significant impacts were not being overlooked, and developing a framework that would allow meaningful integration and discussion of findings for the range of governmental and nongovernmental audiences that this TA is intended and will be extended in breadth and depth during the second and third years.[1]

Discussion of Problems and Issues

As indicated in Chapter 2, policy analysis during the first year has been limited to the preliminary stage of beginning to identify and define some of the major problems and issues with which policymakers making western energy resource development policies will have to deal. It is only now at the end of the first year that the preliminary integration of results in Chapters 3 and 6 through 12 have become available to inform the more focused analyses required to achieve the policy purposes of this TA. Consequently, the discussion of problems and issues in Chapter 13 are limited in scope and are intended to do no more than provide background information that will be useful as the research team shifts its primary emphasis from impact analysis to policy analysis.

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[1] Readers are urged to call errors of fact or interpretation, better and/or additional data sources, and the availability of more adequate analytical tools to the attention of the Science and Public Policy Program-Radian research team.

CHAPTER 6

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE KAIPAROWITS/ESCALANTE AREA

6.1 INTRODUCTION

The Kaiparowits/Escalante area of southern Utah is shown in Figure 6-1. The hypothetical energy resource development proposed in the scenario for this area consists of underground coal mining, mine-mouth electrical power generation, and export of electrical power via extra-high voltage transmission lines to Arizona, California, and elsewhere in Utah.[1] The location of these facilities is shown in Figure 6-2.

In this scenario, construction of the first of two 3,000 megawatts-electric generating plants began during 1975. The first plant will come on-line in 1983 and the second in 1987. Development of the coal mines to supply these plants will begin in 1976, and full production is scheduled for 1987. Details on Kaiparowits/Escalante coal, technological alternatives, and the scenario development schedule are summarized in Table 6-1.

The Kaiparowits/Escalante area is generally characterized by its sparse, homogeneous population, low per-capita income, limited seasonal precipitation, a topography which changes from benchlands in the south to mountains in the north, and vegetation which changes from desert shrubs in the south to pinyon-juniper woodlands and coniferous forests at higher elevations in the north. The area is bounded by several national parks and forests,[2] and the federal government is a major landowner on the plateau.

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[1] While this hypothetical development closely parallels facilities proposed by Southern California Edison, San Diego Gas and Electric, and Arizona Public Service (now cancelled) and the Intermountain Power Project in the Kaiparowits/Escalante area, the development identified here is hypothetical. As with the others, the scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

[2] These are: Bryce Canyon, Zion, Canyonlands, and Capitol Reef National Parks; Glen Canyon National Recreation Area; and Dixie and Kaibab National Forests.

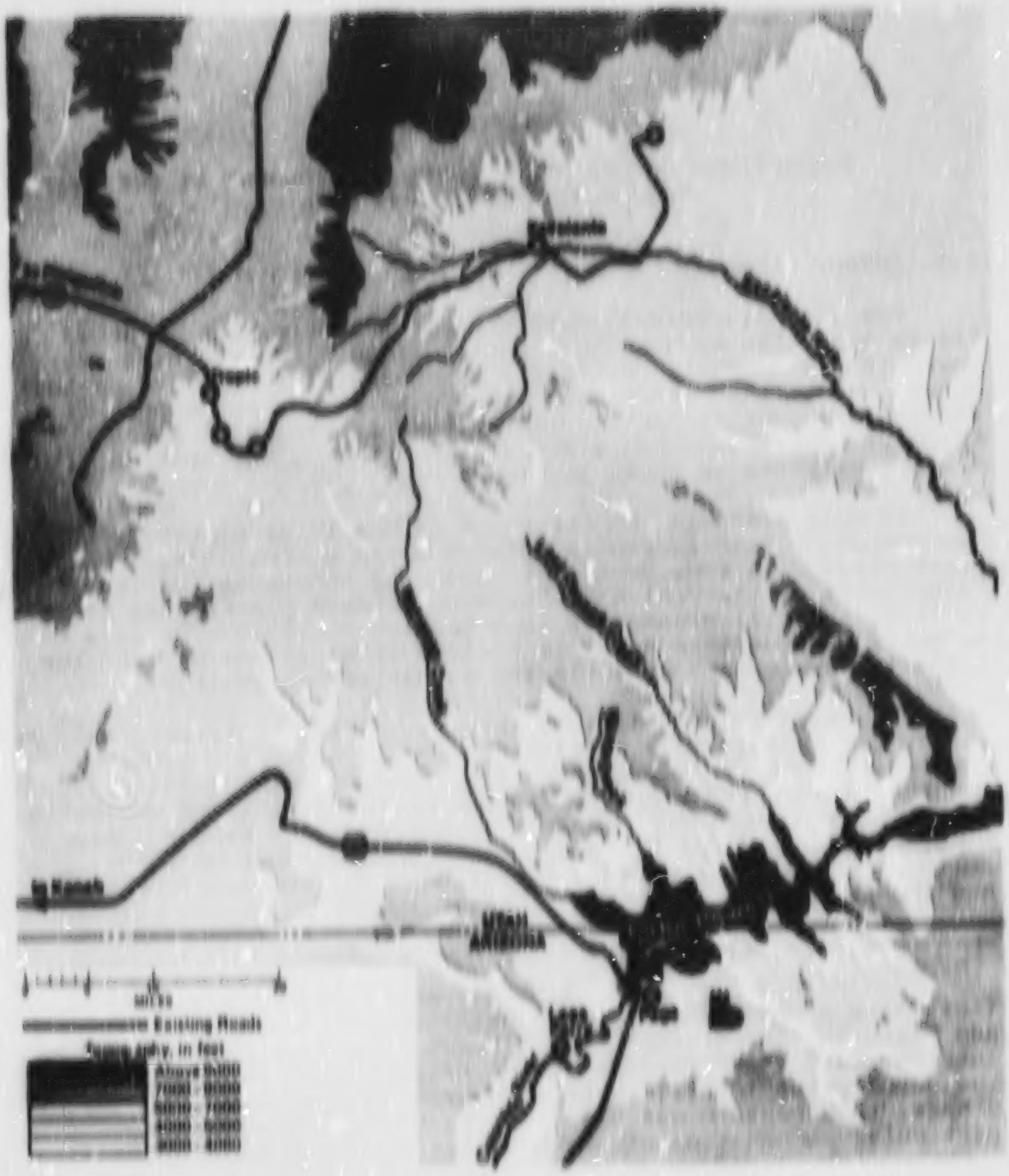

FIGURE 6-1: THE KAIPAROWITS/ESCALANTE AREA OF SOUTHERN UTAH

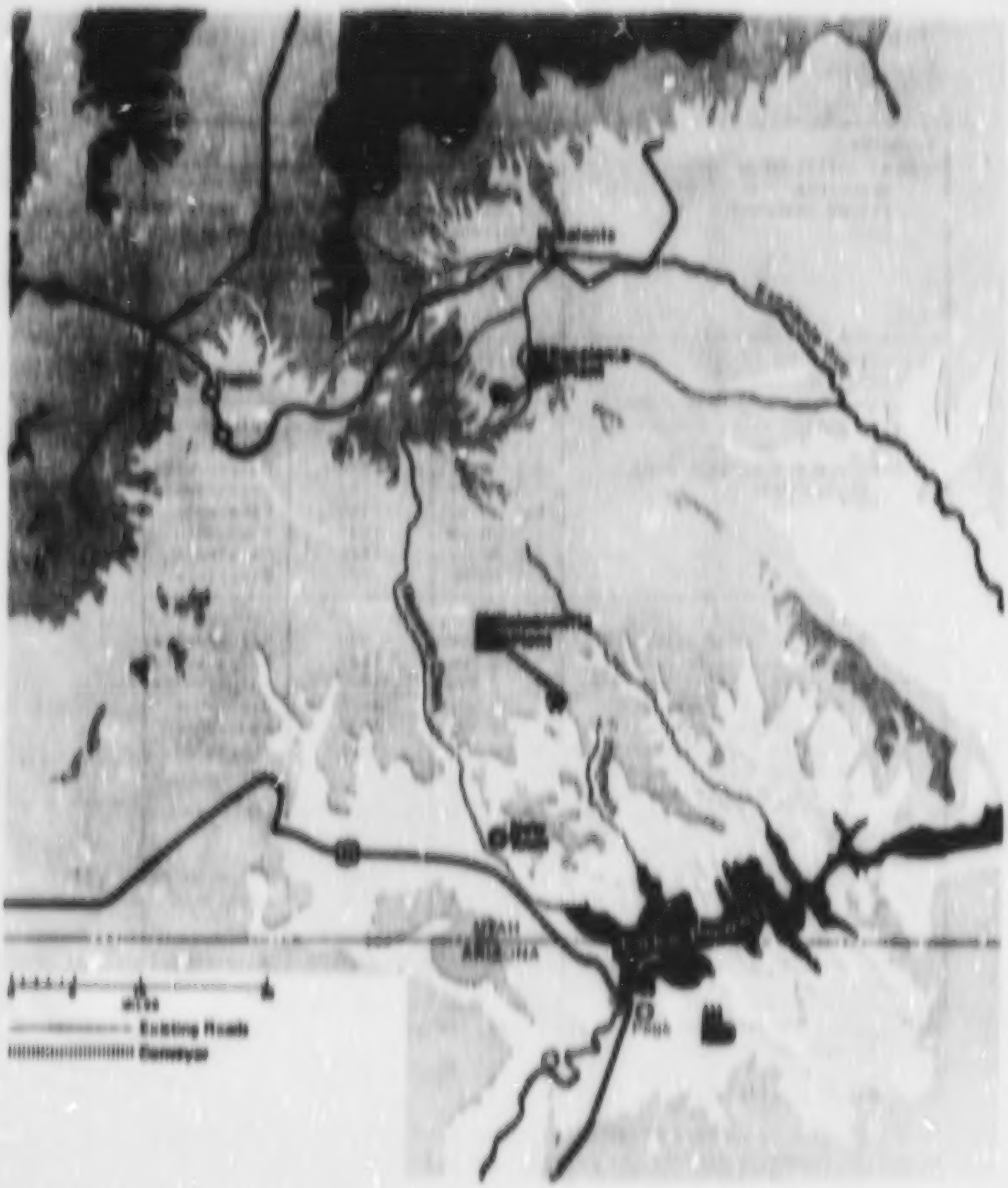

FIGURE 6-2: THE LOCATION OF HYPOTHESIZED ENERGY DEVELOPMENT IN THE KAIPAROWITS/ ESCALANTE AREA

TABLE 6-1: RESOURCES AND HYPOTHESIZED FACILITIES AT KAIPAROWITS/ESCALANTE

Resources		Characteristics	
Coal (billions of tons)		Coal[a]	
Resources	40	Heat Content	10,000 Btu's/lb
Proved Reserves	8	Moisture	10 %
		Volatile Matter	44 %
		Fixed Carbon	40 %
		Ash	9 %
		Sulfur	0.5%

Technologies	Facility Size	Completion Date	Location
Extraction Sixteen underground room-and-pillar mines using continuous miners to produce 1.6 million tons each per year	1.6 MMtpy	1980	Kaiparowits
	1.6 MMtpy	1981	Kaiparowits
	3.2 MMtpy	1982	Kaiparowits
	6.4 MMtpy	1983	Kaiparowits
	1.6 MMtpy	1984	Escalante
	1.6 MMtpy	1985	Escalante
	3.2 MMtpy	1986	Escalante
	6.4 MMtpy	1987	Escalante
Conversion Two 3,000-MWe power plants, each consisting of four 750-MWe turbine generators of 34% plant efficiency and equipped with 99% efficient electrostatic precipitators, 80% efficient limestone scrubbers, and wet forced-draft cooling towers	750 MWe	1980	Kaiparowits
	750 MWe	1982	Kaiparowits
	1,500 MWe	1983	Kaiparowits
	750 MWe	1984	Escalante
	750 MWe	1986	Escalante
	1,500 MWe	1987	Escalante
Transportation Coal Conveyor belt from mines to each power plant (two main conveyors)		1980	Kaiparowits
		1984	Escalante
Electricity Two EHV lines for each 3,000 MWe plant	765 kV	1980	Kaiparowits
	765 kV	1984	Escalante

Btu's/lb = British thermal units per pound
EHV = extra-high voltage
kV = kilovolt
kWe = kilowatt-electric
MMtpy = million metric tons per year
MWe = megawatts-electric

[a]U.S., Department of the Interior, Bureau of Land Management. *Draft Environmental Impact Statement: Kaiparowits Project*, 5 vols. Salt Lake City, Utah: Bureau of Land Management, 1975.

The major sectors of economic activity are government, wholesale and retail trade, and services related to tourism. Ranching is the major agricultural activity. Industrial development has been limited.[1]

Groundwater and surface water are available in the area, the latter primarily from the Colorado River and Lake Powell. Air quality in the area is good, the major present pollutant being blowing dust.

Descriptive characteristics of the area are summarized in Table 6-2. Elaborations of these characteristics are introduced throughout the chapter as required by the impact analyses being discussed.

TABLE 6-2: SELECTED CHARACTERISTICS OF THE KAIPAROWITS/ESCALANTE AREA

Environment	
Elevation	4,000-7,000 feet
Precipitation	6-10 inches annually in the south 20 inches annually in the north
Air Stability	Frequently prolonged winter stagnation
Vegetation	Salt desert shrub in the south; pinyon pine-juniper in the north
Social and Economic[a]	
Land Ownership	
Federal	87 %
State	8 %
City and County	≈.01%
Private	5 %
Population Density	.7 per square mile
Unemployment[b]	
Kane County	7 %
Garfield County	15 %
Income	$2,900 per capita annual

≈ = approximately

[a] 1970 data, Garfield and Kane Counties.

[b] 1974 data.

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[1] U.S., Department of Commerce, Bureau of Economic Analysis, "Local Area Personal Income." *Survey of Current Business* Vol. 54 (May 1974, Part II), pp. 1-75.

6.2 AIR IMPACTS

6.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Kaiparowits/Escalante area is currently affected by the Navajo power plant located near Page, Arizona (Figure 6-1). Measurements of concentrations of criteria pollutants[1] taken prior to 1975 indicated nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) below detection thresholds of the monitoring equipment.[2] However, 24-hour particulate concentrations, ranging from 1 to 543 micrograms per cubic meter ($\mu g/m^3$), violate federal ambient standards (150 $\mu g/m^3$) during high winds due to blowing dust. Monthly average measurements of photo-chemical oxidants ranged from 22 to 74 $\mu g/m^3$, well below the federal standard of 160 $\mu g/m^3$.[3]

Concentrations of four pollutants measured at Page, Arizona during 1970-1974 are summarized in Table 6-3.[4] Based on these

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[1] Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, non-methane hydrocarbons (HC), nitrogen dioxide, oxidants, particulates, and sulfur dioxide. Although technically only non-methane hydrocarbons are covered by the standards, the more inclusive term "hydrocarbons" is generally used. The HC standard serves as a guide for implementation plans to achieve oxidant standards.

[2] See Dames and Moore. *Air Quality Monitoring and Meteorology, Navajo Generating Station--1974*, Status Report, March 15, 1975 as cited in U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976; and Walther, E.G., *et al.* *Air Quality in the Lake Powell Region*. Lake Powell Research Project Bulletin No. 3. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1974.

[3] Although many oxidants exist in the atmosphere, only ozone is measured as a criteria pollutants.

[4] To a slight extent, 1974 concentrations reflect the contribution of the Navajo power plant which became operational in 1974.

TABLE 6-3: AIR QUALITY MEASUREMENTS AT PAGE
(micrograms per cubic meter)

Pollutant Averaging Time	Year	Level		Standards (Federal & State)	
		Dames & Moore[a]	Arizona[b]	Primary	Secondary
Particulates					
Annual	1972	25	31	75	60
	1973	27	52		
	1974	76	48		
24-hour[c]	Ranged from less than 1 to 562 μg/m³. High concentrations primarily due to soil dust.[a]			260	150
SO_2					
Annual	1973	13	1	80	NA
	1974	15	3		
24-hour[c]	1970 to 1974	75	NA	365	NA
	1973	[illegible]	11		
	1974	[illegible]	22		
3-hour[c]	1973	[illegible]	36	NA	1,300
	1974	63	56		
NO_2					
Annual	1973	NA	10	100	100
	1974	NA	26		
Oxidants					
1-hour[c]	1972	84	NA	[illegible]	160

NA = not available or not applicable SO_2 = sulfur dioxide

NO_2 = nitrogen dioxide   μg/m³ = micrograms per cubic meter

[a] Data from: Dames and Moore. *Air Quality Monitoring and Meteorology, Navajo Generating Station—1974.* Status Report. March 15, 1975, as cited in U.S. Department of the Interior. Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project.* 6 vols. Salt Lake City, Utah: Bureau of Land Management. 1976.

[b] Data from: Arizona. Department of Health Services. Bureau of Air Quality Control, as cited in U.S. Department of the Interior. Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project.* 6 vols. Salt Lake City, Utah: Bureau of Land Management. 1976.

[c] Not to be exceeded more than once a year.

measurements, annual average background levels in rural areas are estimated to be:[1]

	µg/m³
Particulates	30
Sulfur dioxide	10
Nitrogen dioxide	4
Oxidants (Ozone)	60

B. Meteorological Conditions

The terrain in the Kaiparowits plateau area of southern Utah is topographically complex. Mesas, plateaus, mountains, hills, canyons, and basins complicate airflow and pollutant dispersion. This terrain can contribute to pollution concentrations which approach ambient standards from elevated and ground-level emissions sources.[2] Highest concentrations will occur when a plume impacts[3] on elevated terrain during stable conditions and when mixing of plumes is limited by temperature inversions at the plume height. Worst-case dispersion conditions are associated with stable conditions, low mixing depths, persistent wind direction, and low wind speeds (less than 10 miles per hour).[4] The frequency with which these conditions occur varies by site.

Meteorological conditions in the area are generally unfavorable for pollution dispersion (i.e., they are stable) about 43 percent of the time. More favorable (unstable) conditions are expected to occur about 20 percent of the time. However, these unstable conditions can contribute to localized, short-term concentrations due to erratic plume movement (plume looping).

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[1] These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are unknown, but high background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are assumed to be relatively low.

[2] Elevated sources are tall stacks that emit pollutants several hundred feet above ground. Ground-level sources include towns, strip mines, and tank farms that emit pollutants close to ground level.

[3] Plume impaction occurs when stack plumes run into elevated terrain because of limited atmospheric mixing and stable air conditions.

[4] Mixing depth is the distance from the ground to the upper boundary of pollution dispersion.

6.2.2 Emissions Sources

The primary emission sources in our Kaiparowits/Escalante scenario are two power plants, supporting underground mines, and population increases. The largest of these sources are the four 750-megawatts electric (MWe) boilers at each power plant site. The 75,000-barrel oil storage tank at the plant, with standard floating roof construction, will emit up to 0.7 pound of hydrocarbons per hour. Emissions from the underground coal mines are expected to be negligible. However, emissions will originate from coal piles, breaking and sizing operations, and transportation at the mines even though dust suppression (water spray) will be used.[1] Pollution from energy-related population in the new town will result primarily from automobiles. Concentrations have been estimated from available data on average emissions per person in several western cities.[2]

The power plants are cooled by wet forced-draft cooling towers. Each cell circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,200 pounds per year.

Table 6-4 displays emissions of five criteria pollutants from the power plants. Most emissions originate from the plants rather than their associated mines. By far the largest quantities of pollution from these plants are nitrogen oxides.

6.2.3 Impacts

A. Impacts to 1980

1. Pollution from Facilities

The hypothetical Kaiparowits power plant will be under construction throughout this period, and construction on the Escalante plant begins in 1979. Few air quality impacts are associated with the construction phase of these plants, although

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[1] The effectiveness of current dust suppression techniques is uncertain. Research being conducted by EPA is investigating this question and will be used to inform further impact analysis.

[2] Refer to the Introduction to Part II for identification of these cities and references to methods used to model urban meteorological conditions. In this scenario, only concentrations for the Kaiparowits new town are modeled.

TABLE 6-4: EMISSIONS FROM POWER PLANTS

Pollutant	Pounds Per Hour[a]	Pounds Per 10^6 Btu's
Particulates	519	0.07
SO_2	1,450	0.19
NO_x	3,764	0.50
CO	348	
HC	105	

Btu = British thermal units
CO = carbon monoxide
HC = hydrocarbons
SO_2 = sulfur dioxide
NO_x = nitrogen oxides

[a] These data represent emissions per 750 megawatts-electric boiler. Each plant in this scenario is hypothetically equipped with four such boilers and runs at full load. A detailed description of each facility is contained in the Energy Resource Development Systems description to be published as a separate report in 1977.

wind-blown dust may increase. Currently dust causes periodic violations of 24-hour ambient particulate standards.[1]

2. Pollution from Towns

Population increases in the area will be concentrated in towns, including the Kaiparowits new town to be built north of Glen Canyon City, Utah. In 1980, this town is projected to have a population of approximately 3,350.[2] Increased emissions from a town this size are expected to result in concentrations of particulates, hydrocarbons (HC), carbon monoxide (CO), SO_2, and NO_2 only slightly higher than current background levels.[3]

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[1] Utah ambient standards are the same as federal standards. Thus references to violations in this chapter include both state and federal.

[2] See Section 6.4.3 for a description of population increases.

[3] Pollution concentrations from population increases were computed under the assumption that urban emissions are directly proportional to population. Computational procedures are elaborated in the Introduction to Part II.

B. Impacts to 2000

1. Pollution from Facilities

The Kaiparowits power plant becomes operational in 1983 and the Escalante plant in 1987. No additional facilities are hypothesized for this scenario through the year 2000. Tables 6-5 and 6-6 summarize concentrations of four pollutants predicted to be produced by the Kaiparowits and Escalante plants. These pollutants (particulates, SO_2, nitrogen dioxide, and HC) are regulated by state and federal primary and secondary ambient air quality standards which are also shown in Tables 6-5 and 6-6.[1] This information indicates that both typical and peak concentrations associated with the power plants, when added to existing background levels, are below ambient standards.[2]

These tables also display Non-Significant Deterioration (NSD) increments, which are allowable increments of pollutants that can be added to areas of relatively clear air (i.e., areas with air quality better than that allowed by ambient air standards).[3] Class I increments, intended to protect the cleanest areas such as national parks, are the most restrictive.[4] Although the Kaiparowits plant meets all allowable Class II increments, concentrations from the Escalante plant exceed Class

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[1] Primary standards are designed to protect public health. Secondary standards are designed to protect public welfare.

[2] Interaction of the pollutants from these two plants may occur if the wind blows directly from one plant to the other. Short-term concentrations which result from interaction would be less than that caused by plume impaction on high terrain, which lies in the opposite direction. However, concentrations from plume interaction would produce higher peak annual averages than would plume impaction. These predicted peak levels are 9 $\mu g/m^3$ of SO_2 and 4.2 $\mu g/m^3$ of particulates. A sensitivity analysis of this siting consideration will be performed during the remainder of the study.

[3] NSD increments apply only to particulates and SO_2.

[4] EPA initially designated all NSD areas Class II and established a petition and public hearing process for redesignating areas Class I or Class III. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

TABLE 6-5: POLLUTION CONCENTRATIONS FROM KAIPAROWITS POWER PLANT
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration[a]				Standard[b]			
			Peak		Ambient[c]		Non-Significant Deterioration	
	Background	Typical	Plant	Kaiparowits	Primary	Secondary	Class I	Class II
Particulates								
Annual	30		1.6	0.1	75	60	5	10
24-hour		2.3	19	4.4	260	150	10	30
SO_2								
Annual	10		4.6	0.1	80		2	15
24-hour		4.4	31	8	365		5	100
3-hour		19	220	22		1,300	25	700
NO_2[d]								
Annual	4		11	0.2	100	100		
HC[e]								
3-hour	unknown	1.4	46	1.1	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical power plant. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and [illegible] are attributable to the [illegible], with the exception of annual SO_2 levels. Concentrations near Kaiparowits are largely attributable to the plant.

[b] "Primary and secondary" refers to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] These are the federal and Utah state standards.

[d] It is assumed that all NO_x from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[e] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 6-4: POLLUTION CONCENTRATIONS FROM ESCALANTE POWER PLANT
(micrograms per cubic meter)

Pollutant, Averaging Time	Concentrations[a]				Standards[b]			
			Peak		Ambient[c]		Non-Significant Deterioration	
	Background	Typical	Plant	Escalante	Primary	Secondary	Class I	Class II
Particulate matter								
Annual	20		6	0.1	75	60	5	10
24-hour		2.3	100	10.8	260	150	10	30
SO_2								
Annual	10		11.3	2.6	80		2	15
24-hour		0.4	291	48	365		5	100
3-hour		29	1,000	95		1,300	25	700
NO_2[d]								
Annual	4		20.2	0.9	100	100		
HC[e]								
3-hour	unknown	1.6	58	0.7	160	160		

SO_2 = sulfur dioxide

HC = hydrocarbons

NO_2 = nitrogen dioxide

[a] These are predicted ground-level concentrations from the hypothetical power plant. Annual average background levels are considered to be the best estimate of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Escalante are largely attributable to the plant.

[b] "Primary and secondary" refers to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas in relatively clean air, such as national forests. These standards are discussed in detail in Chapter [illegible].

[c] These are the federal and Utah state standards.

[d] It is assumed that all NO_x from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[e] The 3-hour HC standard is measured at 6-9 a.m.

II increments for 24-hour particulates and SO_2 and 3-hour SO_2 levels. Both plants violate all Class I increments except for annual particulates.

Since these plants exceed Class I increments, they would have to be located far enough away from potential Class I areas to allow emissions to be diluted by atmospheric mixing to the low concentrations allowed by Class I increments. The distance required for this dilution varies by facility type, size, emission controls, and meteorological conditions. In effect, this requirement establishes a "buffer zone" around Class I areas.

Due to the complex terrain in the Kaiparowits/Escalante area, no one buffer zone size for potential Class I NSD areas can be defined. However, the 3-hour SO_2 increment for potential Class I areas may be exceeded in Bryce Canyon National Park, located about 25 miles to the west.[1] (Figure 6-3.) Other nearby Class II areas which may be redesignated Class I include: Zion, Capitol Reef, and Grand Canyon National Parks; Dixie and Kaibab National Forests; and Grand Canyon National Recreation Area.[2]

2. Pollution from the Town

The Kaiparowits new town population is expected to increase from 3,350 in 1980 to 6,940 in 1990 and 7,290 in 2000. This growth will contribute to increases in pollution concentrations due solely to urban sources. Table 6-7 shows predicted 1990 concentrations of five criteria pollutants measured in the center of town and at a point 3 miles from the center of town.[3] When concentrations from urban sources are added to background levels and to concentrations from the power plant (Tables 6-5 and 6-6), the hydrocarbon levels exceed ambient standards.[4] No other standard is approached by these concentrations.

Current NSD increments are designed to restrict pollution from large point sources (e.g., power plants), not from urban

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[1] This estimate is based on the Radian Corporation's best professional judgment.

[2] These are "potential" Class I areas both because their current air quality makes them prime candidates for redesignation and because recent Congressional legislation, although not enacted into law, has singled out national parks, forests, and recreation areas for mandatory Class I status.

[3] Concentrations in 2000 will be about 5 percent higher than for 1990.

[4] Ambient hydrocarbon standards are violated regularly in most urban areas.

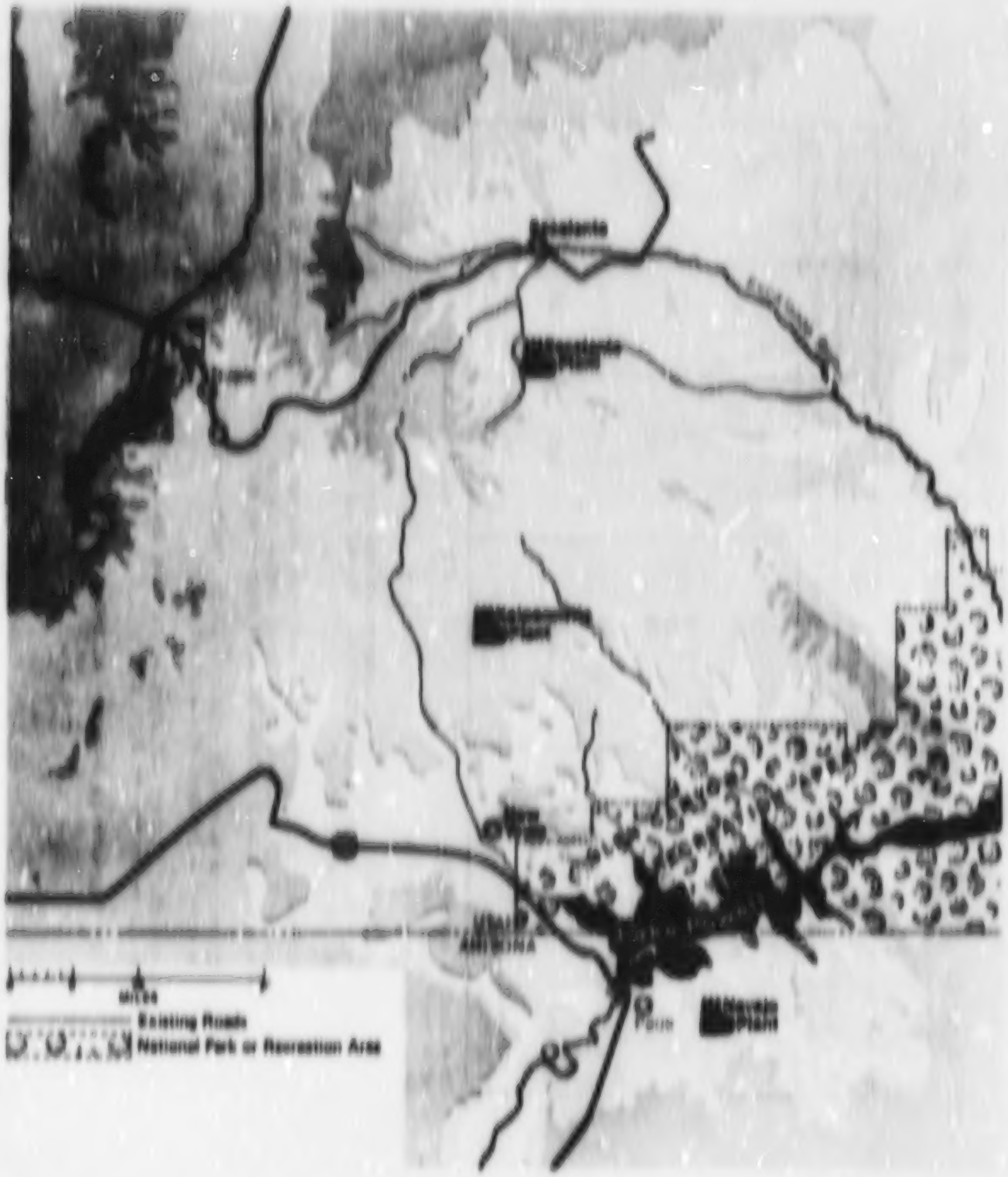

FIGURE 6-3: AIR IMPACTS OF ENERGY FACILITIES IN THE RIFLE SCENARIO

TABLE 6-7: PREDICTED CONCENTRATIONS AT [illegible] NEW TOWN IN 1990
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]			Standards[b]	
	Background	Mid-Town Point[c]	Rural Point	Primary	Secondary
Particulates					
Annual	20	25	4	75	60
24-hour	20	56	56	260	150
SO_2					
Annual	10	8	2	80	
24-hour	13	27	27	365	
3-hour	15	40	40		1,300
NO_2[d]					
Annual	4	26	6	100	100
HC[e]					
3-hour	unknown	481	481	160	160
CO					
8-hour	unknown	1,606	1,606	10,000	10,000
1-hour		2,522	2,622	40,000	40,000

CO = carbon monoxide
HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and secondary" are federal and Utah ambient air quality standards designed to protect the public health and welfare, respectively. Except for annual standards, these limits are not to be exceeded more than once per year.

[c] 1980 concentrations are only slightly higher than background. Concentrations in 2000 will be about 5 percent higher than 1990.

[d] It is assumed that 50% of nitrogen oxide from urban sources is converted to NO_2. Refer to the introduction to Part II.

[e] The 3-hour HC standard is measured at 6-9 a.m.

sources (e.g., automobiles). Table 6-6 shows that particulate concentrations solely from urban sources exceed Class II increments. Thus, if the same NSD criteria were applied to urban sources as are currently applied to industrial sources, population increases in the Kaiparowits new town would violate NSD standards.

6.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories of potential impacts are sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

A. Sulfates

Very little knowledge exists about sulfate concentrations likely to result from western energy development. In part, this is attributable to the very small particle size (in the submicron range) of sulfate products, which increases the difficulty of modeling atmospheric concentrations. Some information is available on sulfate concentrations resulting from oil shale retorting and coal gasification and is summarized in the air sections of Chapters 7-11. Generally, sulfates are products of chemical reactions in the atmosphere rather than emissions from energy facilities. For example, sulfuric acid, derived from the oxidation of SO_2, can react with other components in the atmosphere to produce such salts as ammonium sulfate.

B. Oxidants

Oxidants, which include compounds such as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and bromine, can be emitted from specific sources or formed in the atmosphere. For example, oxidants can be formed when HC combine with nitrogen oxides.

Under present air quality laws, only ozone is measured and compared to ambient standards. Considerable uncertainty exists concerning the potential impacts of other oxidants.

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analysed during the remainder of the project. See: Hazardous Materials Advisory Committee. *Nitrogenous Compounds in the Environment*, U.S. Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

Too little is known about the actual conversion processes which form oxidants to be able to predict concentrations from power plants. However, the relatively low peak concentrations of HC from the Kaiparowits (58 $\mu g/m^3$) and Escalante (46 $\mu g/m^3$) plants suggest that an oxidant problem is unlikely to result from that source alone. An oxidant problem is more likely to result from the combination of background HC and the high levels of nitrogen dioxide emitted in the power plant plume. Since background HC levels are unknown, the extent of this problem has not been predicted.

Concentrations of HC over the Kaiparowits new town, which may be three times higher than the federal standard by the year 2000, are also likely to create an oxidant problem. Since oxidant formation may occur relatively slowly (i.e., one or more hours), this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Fine Particulates

Fine particulates, those less than 3 microns in diameter, are primarily ash and coal particles emitted by the plants.[1] They are also produced by chemical reactions in the atmosphere (e.g., sulfates and nitrates). Both sources can produce health impacts and reduce visibility.

In this scenario, most of the fine particulates are ash particles emitted by the power plants. Current information suggests that particulate emissions controlled by electrostatic precipitators (ESP) have a mean diameter of less than 5 microns and uncontrolled particulates have a mean diameter of about 10 microns.[2] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles remaining. The high-efficiency ESP's (99-percent removal) in this scenario are estimated to produce fine particulates which account for about 50 percent of the total particulate concentrations. Health effects from fine particulates are discussed in Section 12.6.

D. Long-Range Visibility

One impact of very fine particulates (0.1-1.0 microns in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light, which reduces the contrast between an object and its background eventually below levels required by the human eye to distinguish the object from the background. Estimates of visual ranges for this scenario are based on empirical relationships between visual distance and fine particulate concentrations.[1]

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[1] The time required to produce fine particulates by atmospheric chemical reactions usually insures that they will form considerable distances from the plant.

[2] Fifty percent of the mass is contained in particles this diameter. Eppright, B.R., *et al.* *A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station, Final Report*, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

Visibility in the region of this scenario averages about 70 miles. Average visibility for an observer at Navajo point looking northwest will decrease to 65 miles after the Kaiparowits plant is in operation and to 63 miles after both plants are in operation. Air stagnation episodes, most likely on winter mornings, will cause further reductions.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although the 99-percent efficient ESP hypothesized in this scenario will remove enough particulates for power plants to meet emission standards, stack plumes would probably still exceed the 20-percent opacity standard.[2] Thus, plumes will be visible at the stack exit and for some distance downwind. A particulate removal efficiency of 99.5 percent would meet the 20-percent opacity regulation.

F. Cooling Tower Salt Deposition

Salt deposition rates from cooling tower drift for the power plants in this scenario are estimated to be about 80 pounds per acre per year (lb/acre/yr) out to a distance of about 1 mile.[3]

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[1] Extrapolation from empirical relationships to this scenario are based on the Radian Corporation's professional judgment. For an elaboration of the empirical relationships see: Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." Atmospheric Environment, Vol. 2 (September 1968), pp. 455-464. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

[2] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal units heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require such high efficiencies (99.5) and thus would increase electrostatic precipitators costs.

[3] This estimate is based on the Radian Corporation's professional judgment.

This will decrease rapidly to 7 lb/acre/yr from 1 to 8 miles and to 0.6 lb/acre/yr from 8 to 13 miles. The Kaiparowits and Escalante power plants are far enough apart (about 32 miles) so that little interaction between cooling tower plumes will occur. Impacts of salt deposition on vegetation are discussed in Section 6.5.

G. Cooling Tower Fogging and Icing

In southern Utah, fogging and/or icing conditions occur infrequently during the spring, summer, and fall because the area is normally very dry. Average relative humidity in the area ranges between 37 and 50 percent during these seasons. In the winter, the significantly higher relative humidities (73 percent average) contribute to dense fogs which are common to the area. Average subfreezing winter temperatures also create icing. Power plants will worsen both these winter conditions and contribute to occasional ice fogs (cold droplets which freeze on contact).

6.2.5 Summary of Air Impacts

A. Air Quality

Two new 3,000-MWe power plants are hypothesized for the Kaiparowits/Escalante scenario. No federal or state ambient standard is expected to be violated by these facilities. However, several PSD increments will be exceeded. Concentrations from the plant at Escalante will exceed short-term Class II increments for both particulates and SO_2, and concentrations from both plants exceed Class I 24-hour particulate and all SO_2 increments. Although no one buffer zone can be established for these plants because of the complex terrain in the area, several nearby national parks, forests, and recreation areas are potential Class I areas.

Population increases in the Kaiparowits new town will add to and create pollution problems. Except for SO_2, peak concentrations from urban sources will be higher than those from the energy facilities and are expected to violate ambient HC levels by 1980. Concentrations from the new town are also predicted to exceed Class II PSD increments for particulates by 1990.

Several other categories of air impacts have received only preliminary attention. Our information to date suggests that an oxidant problem is likely to occur over the new town and that problems associated with sulfates and fine particulates may also arise. Plumes from the stacks at both plants may exceed the 20-percent opacity standard, and long-range visibility will be reduced.

TABLE 6-8: CONCENTRATIONS FROM MINIMAL EMISSIONS CONTROLS[a]
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations		Standards (Federal and Utah)	
	Kaiparowits Plant	Escalante Plant	Primary	Secondary
Particulate				
Annual	2.3	5.8	75	60
24-hour	26	152	260	150
SO_2				
Annual	22	56	80	-
24-hour	253	1,467	365	-
3-hour	1,147	3,320	-	1,300
NO_x				
Annual	19	49	100	100

NO_x = nitrogen oxides
SO_2 = sulfur dioxide

[a] These are maximum concentrations which assume 98.6 percent particulate removal and no SO_2 removal, which would meet New Source Performance Standards.

B. Alternative Emission Controls

Pollution concentrations from the power plants would vary if emission control systems with other efficiency levels were used. As currently configured, the plants have greater control than required to meet most New Source Performance Standards (NSPS).[1] The plants could meet NSPS with 98.6-percent efficient electrostatic precipitators and without any SO_2 removal. Table 6-8 shows concentrations of SO_2, particulates, and NO_x which would result from the use of these less-efficient controls. These data show that concentrations from the Escalante plant would violate particulate and SO_2 standards, and both plants would exceed PSD increments for 24-hour and 3-hour SO_2.

Other alternatives are for the plants to increase emission control efficiency or to reduce total plant capacity to meet all PSD Class II increments. The information in Table 6-9 shows that 61-percent (Kaiparowits plant) and 93-percent (Escalante plant)

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[1] The probable exception to this pattern is for plume opacity. NSPS limit pollution emissions from stationary sources. Different regulations apply to different sources.

TABLE 6-9: ALTERNATIVES FOR MEETING CLASS II INCREMENTS

Pollutant Averaging Time	Required Emission Removal (%)		Plant Capacity (MWe)
	Kaiparowits Plant	Escalante Plant	Escalante Plant
SO_2			
Annual	32	73	3,000
24-hour	61	93	1,020
3-hour	39	87	1,970
Particulates			
Annual	93.8	97.5	3,000
24-hour	98.3	99.7	850

MWe = megawatts-electric
SO_2 = sulfur dioxide

removal would be required to meet all allowable SO_2 Class II increments. The Kaiparowits plant would require 98.3-percent and the Escalante plant 99.7-percent removal to meet particulate increments.[1] Alternatively, the Escalante plant could meet Class II requirements by reducing capacity to 850 MWe.[2] The Kaiparowits plant meets Class II increments, given hypothesized removal efficiencies.

C. Data Availability

Availability and quality of data have limited the impact analysis reported in this chapter. These factors have primarily affected estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials. Expected improvements in data and analysis capacities include:

1. Improved understanding of pollutant emissions from electrical generation. This includes the effect of pollutants on visibility.

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[1] These efficiencies appear technologically feasible. More attention will be paid to technological feasibility of highly efficient control systems during the remainder of this project.

[2] This assumes concentrations are directly proportional to megawatt output.

2. More information on the amounts and reactivity of trace elements from coals. This would improve estimates of fallout and rainout from plumes.

6.3 WATER IMPACTS

6.3.1 Introduction

Surface water from Lake Powell will be the major water source for energy development in the Kaiparowits/Escalante scenario. (see Figure 6-4). Precipitation in the Kaiparowits/Escalante area ranges from 6-10 inches per year in the southern areas to 20 inches per year in the Escalante mountains. Annual snowfall ranges from 12 to 24 inches.[1]

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

6.3.2 Existing Conditions[2]

A. Groundwater

Three aquifer systems are present in the Lake Powell area: small alluvial aquifers in deposits along rivers and streams, perched aquifers[3] in the coal-bearing Straight Cliffs geologic formation, and a regional aquifer in the deep Navajo sandstone.

Alluvial aquifers are located in sand and gravel strata below valley stream beds. The water table in these shallow aquifers is generally less than 100 feet below the surface. The aquifers generally discharge into streams and are recharged by the streams and by underflow from perched aquifers. While the quality is generally good (depending on stream quality), the quantity of water available from alluvial aquifers is quite small.

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[1] The moisture content of one inch of rain is equal to approximately 15 inches of snow.

[2] Available data for describing the natural ground and surface water conditions in the scenario area are sketchy. The primary data source is the environmental impact statement prepared for the proposed Kaiparowits coal-fired power plant. U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[3] Perched aquifers are small, usually localized aquifers that are above the true water table.

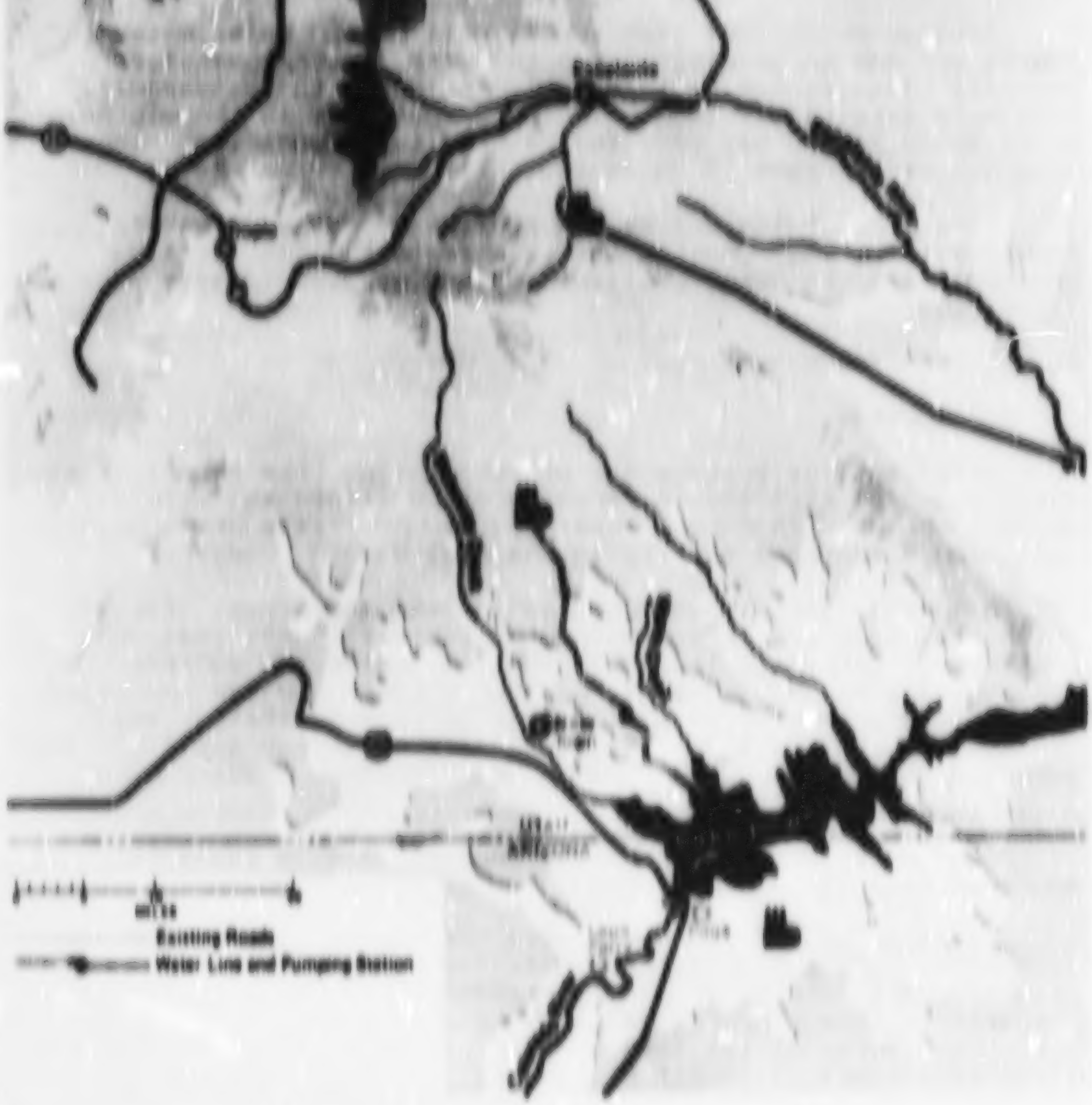

FIGURE 6-4: WATER SUPPLIES AND PIPELINES FOR THE KAIPAROWITS/ESCALANTE SCENARIO

The perched aquifers in the Straight Cliffs Formation, the formation in which the minable coal is located, are located in sandstone bodies that are generally small and erratically distributed in shale. Water yields vary from less than 1 to about 50 gallons per minute (gpm). These shallow aquifers are recharged by the direct infiltration of precipitation, and discharge is from seeps and springs. The water in these aquifers, which is relatively poor quality (total dissolved solids ranges around 1,000 milligrams per liter, mg/ℓ), is used by livestock and wildlife.

The most important regional aquifer is located in the Navajo sandstone at a depth of 1,000-2,000 feet in the vicinity of the illustrative power plants. This aquifer is not presently being used in the Kaiparowits area. At lower elevations along Wahweap Creek, where the aquifer is quite shallow, wells yield from several hundred to more than 1,000 gpm. Recharge of this regional aquifer is in the area where the sandstone crops out, and most of the discharge is probably into Lake Powell. The quality of the groundwater in the aquifer varies from fresh to slightly saline (up to 3,000 mg/ℓ).

Although groundwater is used exclusively by some of the area's inhabitants, it is high in hardness and exceeds several of the recommended limits set for drinking water as shown in Table 6-10.

B. Surface Water

The only major perennial river in the Kaiparowits area is the Colorado River. Glen Canyon Dam, which forms Lake Powell, is located 16 miles up the Colorado River from Lee Ferry,[1] the official division between the Upper and Lower Colorado River Basins, and 5 to 10 miles downstream from the scenario site. At the normal water surface elevation, Lake Powell extends 186 miles up the Colorado River and 71 miles up the San Juan River.

The lake operates under the criteria established by the Secretary of the Interior to control flows in the Colorado River at Lees Ferry to meet conditions of the Colorado River Compact.[2] For hydroelectric power generation, a minimum pool elevation must be maintained. Normal releases are approximately 10 percent of the cumulative 10-year flow required by the Colorado River Compact (75 million acre-feet), plus an allocation of Upper Basin

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[1] Lee Ferry, the designated division point on the river, is located near the town of Lees Ferry, Arizona.

[2] Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

TABLE 6-10: GROUNDWATER QUALITY

Substance	Drinking Water Recommended Limits mg/l[a]	Navajo Sandstone Aquifer		Straight Cliffs Formation	
		Sample[b] Well #19 (mg/l)	Sample[b] Well #20 (mg/l)	Drill[c] Hole #3 (mg/l)	Drill[c] Hole #10 (mg/l)
Arsenic	0.05			0.002	0.003
Barium	1.0			0.02	0.05
Cadmium	0.01			0.01	0.05
Chloride	250[d]	140	18		
Chromium	0.05[e]			0.02[f]	0.42[f]
Copper	1[d]			0.03	0.43
Cyanide	No Standard			0.005	0.005
Fluoride	1.4-2.4[g]	0.6			
Iron	0.3[d]	0.03	7.40		
Lead	0.05			0.13	0.38
Mercury	0.002			0.001	0.001
Nitrate	10[h]	0.11[i]	0.13[j]		
Selenium	0.01			0.001	0.003
Silver	.05				
Sulfate	250[d]				
Zinc	5[d]			0.3	4.98
Dissolved Solids	500[d]	1,060	297		

mg/l = milligrams per liter

[a] U.S., Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," 40 Fed. Reg. 59566-88 (December 24, 1975). These regulations also include standards for turbidity, organic chemicals, and microbiological contaminants.

[b] U.S., Department of the Interior, Bureau of Land Management, *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. II-167.

[c] Ibid., p. II-149.

[d] U.S., Environmental Protection Agency, "National Secondary Drinking Water Regulations," Proposed Regulations, 42 Fed. Reg. 17143-47 (March 31, 1977).

[e] As Chromate (Cr^{+6}).

[f] Total chromium.

[g] Fluoride standard varies according to the annual average of the maximum daily air temperature for the location in which the community water system is situated. The lowest level is for temperatures above 26.3° C, and the highest level is for temperatures below 12° C.

[h] Measured as Nitrogen.

[i] Nitrate (NO_3) + Nitrite (NO_2) as Nitrogen.

[j] Nitrate (NO_3).

flow assumed to be required by treaty with Mexico.[1] This totals approximately 8.25 million acre-feet per year (acre-ft/yr). Basic storage and water quality data for Lake Powell are presented in Table 6-11. Water quality data can be compared to typical industrial boiler feed water requirements, which are also shown.

TABLE 6-11: STORAGE AND WATER QUALITY DATA FOR LAKE POWELL

Minimum power pool elevation	3,490 feet above mean sea level
Maximum water level	3,711 feet above mean sea level
Dead storage	1,998,000 acre-feet
Active storage below minimum power pool elevation	4,126,000 acre-feet
Active storage above minimum power pool elevation	20,876,000 acre-feet

Water Quality Data from U.S.G.S. Sampling Station No. 1, Colorado River Channel above Mouth of Wahweap Creek, unpublished, 1974, 1975.

Parameter	Range of Values (mg/ℓ)		Typical Boiler Feed Water[a]
	Minimum	Maximum	
Dissolved Solids	475	677	<10
Calcium	58.4	85	0.10
Magnesium	21.7	29.8	0.03
Sodium	60.3	93.8	0.24
Potassium	3.5	5.1	<0.01
Carbonate		23.1	
Bicarbonate	107	182	<0.01
Chloride	38	70.3	<10
Sulfate	157	281	0.14
Dissolved Oxygen	4	10.1	

mg/ℓ = milligrams per liter   < = less than

[a] American Water Works Association, Inc., Water Quality and Treatment, 3rd ed. New York, N.Y.: McGraw-Hill, 1971, p. 510, Table 16-1. Some numbers derived from Table 16-1, assuming concentrating factor = 100, high-pressure drum type boiler.

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[1] Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

TABLE 6-12: ESTIMATED 1975 SURFACE WATER RESOURCES AND USES FOR UTAH IN THE UPPER COLORADO RIVER BASIN[a]
(1,000 acre-feet)

Average Annual Water Supply	
Modified Inflow to Region	8,759
Undepleted Water Yield	2,651
Estimated 1975 Imports	3
Total Water Supply	11,413
Estimated 1975 Water Use	
Irrigation	521
Municipal and Industrial Including Rural	7
Minerals	9
Thermal Electric	8
Recreation and Fish and Wildlife	8
Other	118
Reservoir Evaporation	194
Estimated 1975 Exports	112
Total Depletions	977
Estimated Future Water Supply	
Remaining Available 1975 Water Supply	10,436
Estimated Allocations for Future Use	10,255
Net Water Available for Future Use	181

[a] U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, pp. 374-375.

The estimated 1975 surface water supply and uses in Utah are shown in Table 6-12. Irrigation is the largest water user. The hypothetical energy developments in this scenario will increase power generation usage by a factor of 10 but will still be less than 20 percent of the water used for agriculture.

The local surface water system which will be directly affected by the Kaiparowits/Escalante energy development includes several ephemeral and intermittent streams. Flow in these streams is generally the result of cloudbursts that occur frequently in late summer. The mean annual runoff for these streams is as follows:[1]

Stream	Acre-ft/yr[2]
Warm Creek	1,000
Wahweap Creek	2,000
Last Chance Creek	2,800
Escalante River	12,900

Peak flood flows in these creeks can be considerable. For example, where Coyote and Wahweap Creeks come together, flows have a 50-percent probability of attaining 2,000 cubic feet per second (cfs) once every 2 years.

Water quality in these ephemeral and intermittent streams has been sampled. Although the antecedent conditions are not known, values for estimated flow and total dissolved solids (TDS) during May 1974 were:[3]

	Flow (cfs)	Total Dissolved Solids (mg/l)
Wahweap Creek	1.0	2,140
Warm Creek	very low	4,710
Last Chance Creek	very low	3,520
Escalante River	2.6	1,150[4]

Under the Upper Colorado River Basin Compact,[5] Utah is entitled to 23 percent of the water allocated to the Upper Basin after 50,000 acre-ft/yr is deducted for Arizona. Primarily because of variations in calculated values for total flow and the portion of the Mexican Treaty which may be allocated to the Upper Basin, Utah's share of the Upper Basin water is uncertain. However, a range of from 1,322,500 to 1,437,500 acre-ft/yr appears to be a reasonable estimate.

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[1] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, Chapter 3, p. 3-156.

[2] 1,000 acre-ft/yr corresponds to 1.38 cubic feet per second.

[3] BLM. FEIS: Kaiparowits, p. 3-157.

[4] From U.S. Geological Survey Water Resource Data, transformed from specific conductance measurement to TDS using Hem, John D. Study and Interpretation of the Chemical Characteristics of Natural Water, 2d ed., U.S. Geological Survey Water-Supply Paper 1473. Washington, D.C.: Government Printing Office, 1970, Figure 10.

[5] Upper Colorado River Basin Compact of 1948, 63 Stat. 31 (1949).

6.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements for energy facilities hypothesized in the Kaiparowits/Escalante scenario are shown in Table 6-13. Two sets of data are presented. Energy Resource Development data are based on secondary sources including impact statements, Federal Power Commission docket filings, and recently published data accumulations.[1] Water Purification Associates data are from a study on minimum water requirements and take into account the moisture content of the coal being used and local meteorological data.[2]

Figure 6-5 shows water requirements for the 3,000-MWe power plant at Kaiparowits/Escalante. As indicated, the greatest amount of water will be consumed by wet cooling. Process requirements are small, and solids disposal consumes only 5.5-14 percent of the total, depending on which of the estimates is used.

The water required for mining will be used predominately for dust control and coal washing. No water requirement for reclamation is assumed for the underground mines.

Lake Powell is the designated source of surface water for the hypothetical energy development at the Kaiparowits/Escalante site. To obtain the necessary water for energy development, the developer must acquire a water right from the state of Utah (or

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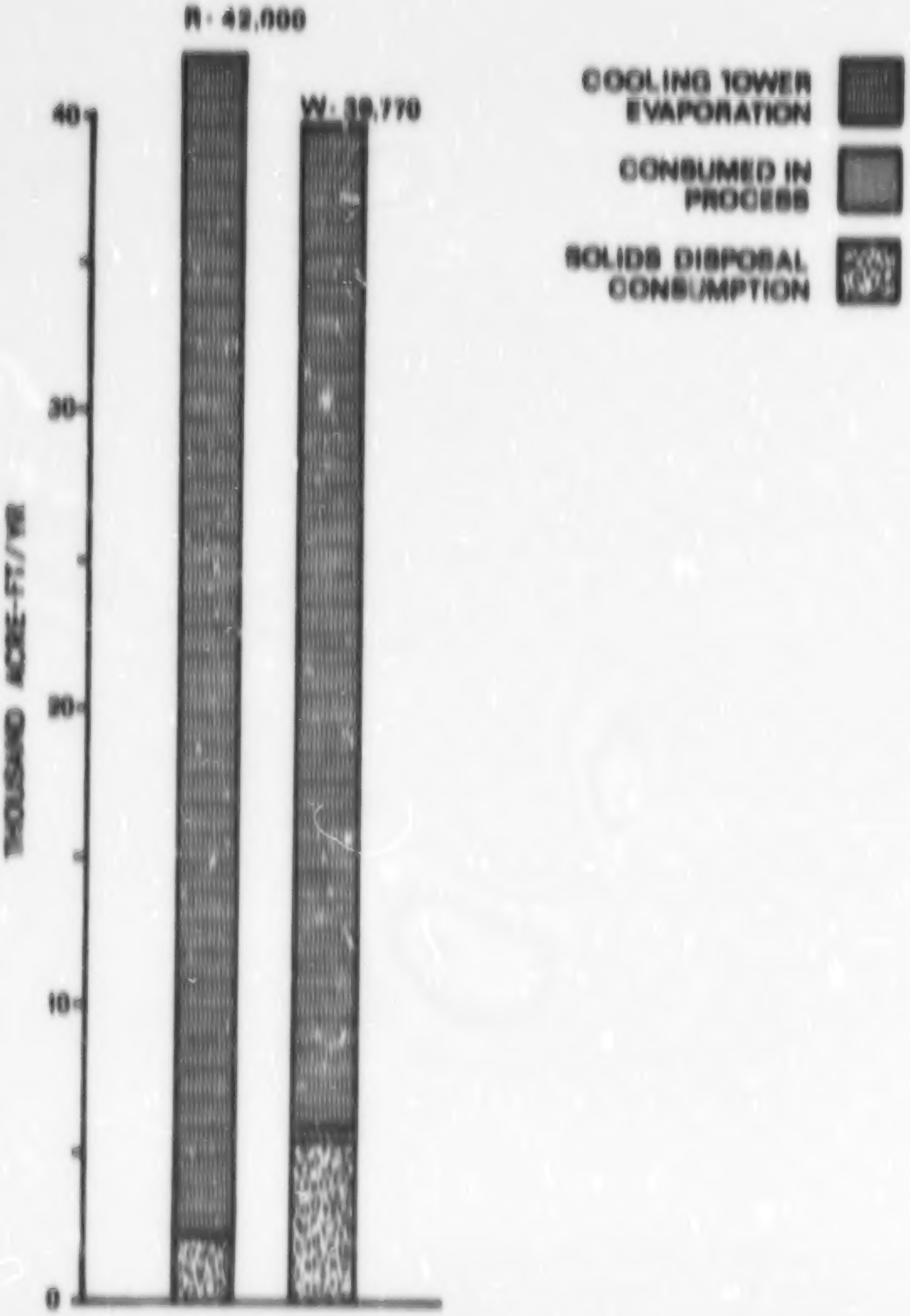
[1] See White, Irvin L., et al. Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. These ERDS are based on data drawn from: University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975. Radian Corporation. A Western Regional Energy Development Study. Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

[2] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.



6-5: WATER CONSUMPTION FOR A 3,000 MWe POWER PLANT AT KAIPAROWITS/ESCALANTE

TABLE 6-13: WATER REQUIREMENTS FOR ENERGY DEVELOPMENT AT KAIPAROWITS/ESCALANTE

Use	Size	Requirements[a] (acre-feet per year)	
		ERDS[b]	WPA[c]
Power Plant (2 plants)	6,000 MWe (3,000 each)	84,000	79,540
Coal Mining	25.4 x 10^6 tpy	6,560	3,542
Limestone Quarry	322,000 tpy	4[d]	

ERDS = energy resource development system
MWe = megawatt(s)-electric
tpy = tons per year
WPA = Water Purification Associates

[a] Requirements are based on an assumed load factor of 100 percent. Although not realistic for sustained operation, this load factor indicates the maximum water demand for these facilities.

[b] Chapter 3 of White, Irvin L., et al. Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c] From Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[d] Scaled from U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project. 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

purchase water from the holder of an existing water right) and must enter into a contract with the Department of the Interior if water is to be drawn from the lake rather than from a naturally flowing watercourse within Utah.

As shown in Figure 6-4, water intakes are to be located at Warm Creek for the Kaiparowits plant and in the flooded portion of the Escalante River at Willow Creek for the Escalante plant.

Groundwater resources are not sufficient to meet the needs of the energy facilities.

Water for the coal mines and limestone quarries will be taken from groundwater supplies.

B. Municipalities

The water needs of the expected increases in population are shown in Table 6-14. An estimated 10,753 acre-ft of water will be needed annually for the new town. This unusually high water demand is caused by the new town development plan, which calls for extensive greenbelts and park facilities to attract necessary personnel to the area.[1]

Rural water demands will be met by individual wells that probably will not significantly affect the local aquifer. Municipal water requirements will be supplied by groundwater pumped from a well field in the Navajo sandstone. Most of this withdrawal

TABLE 6-14: EXPECTED INCREASES IN WATER SUPPLY REQUIREMENTS

Increased Water Requirement Above 1975 Level (acre-feet per year)					
Year	Kanab[a]	Panguitch[b]	Escalante[a]	Page[a]	Kaiparowits New Town[c]
1980 1990 2000	21.0 63.0 70.0	17.5 105.0 140.0	7.0 567.0 588.0	84 476 574	1,770 10,266 10,753

[a]Based on 125 gallons per capita per day (gcd).

[b]Based on 313 gcd (Panguitch City Clerk).

[c]Based on 790 gcd (approximately 125 gcd for domestic use and 665 gcd for greenbelt irrigation).

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[1] U.S., Department of the Interior, Bureau of Land Management, Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

will probably be from bank storage of Lake Powell, so this source should be as reliable as the water supply of the lake. If it can be demonstrated that the groundwater used is part of the Lake Powell bank storage,[1] the water will be considered Colorado River water and may be subject to the legal constraints of the applicable compacts. Also, existing local groundwater users could be affected by the new town's well field. These legal conflicts would have to be resolved before a new water right could be issued.

6.3.4 Effluents

A. Energy Facilities

The quantities and types of waste streams from the energy facilities hypothesized for the Kaiparowits and Escalante scenario areas are shown in Table 6-15. Fly ash disposal, flue gas desulfurization, and coal washing generate the largest quantities of residuals. (Coal from the underground mines will be washed to reduce the ash and sulfur levels.) Other residual quantities are insignificant. All these waste streams are ponded; there are no intentional releases to surface or groundwater systems.

All discharge streams from the facilities will be discharged into clay-lined, on-site evaporative holding ponds. Runoff prevention systems will be installed in all areas that have a pollution potential. Runoff will be directed to either a holding pond or a water treatment facility.

B. Municipalities

Waste disposal is assumed to be by individual, on-site facilities (septic tanks and drainage fields) in rural areas and by treatment facilities in urban areas. Wastewater increases resulting from the expected population increases associated with energy development are shown in Table 6-16.

Current treatment practices in Escalante and Panguitch consist entirely of septic tanks and drainage fields. Kanab has a two-stage 0.2-mgd (million gallons per day) trickling filter operating at about 0.17 mgd. As a result of the increased populations, municipal sewage treatment facilities will probably need to be built in Escalante and Panguitch as well as the new town. New facilities should use best practicable waste treatment technologies to conform to 1983 standards and should allow recycling

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[1] Some water migrates into the banks of the lake and is stored there, hence the term "bank storage".

TABLE 5-15: RESIDUALS FROM ELECTRIC POWER GENERATION AT KAIPAROWITS/ESCALANTE[a]

	Stream Content[b]	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solid (gpm)
Boiler Demineralizer Waste	s	3.3	1.7	0.3
Treatment Waste	i	376	149	37.1
Flue Gas Desulfurization	-	2,014	806	201
Bottom Ash Disposal	i	593	456	22.9
Fly Ash Disposal	i	2,274	1,820	75.7
Coal Washing (coarse reject)	i	6,381	4,020	75
Coal Washing (tailings)	i.o	9,084	3,164	466
Total		20,723	10,817	876

gpm = gallons per minute
tpd = tons per day

[a] From Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[b] s = primarily soluble inorganic
i = primarily insoluble inorganic
o = primarily insoluble organic

TABLE 6-16: EXPECTED INCREASES IN WASTEWATER FLOWS

	Increased Flow Above 1975 Level[a] (million gallons per day)				
Year	Kanab	Panguitch	Escalante	Page	Kaiparowits New Town
1980	.015	.005	.005	.27	0.05
1990	.045	.030	.410	.66	1.16
2000	.050	.040	.420	.73	1.22

[a] Based on 100 gallons per capita per day.

or zero discharge of pollutants to meet 1985 standards.[1] The 1985 standard could be met by using effluents for industrial process make-up water or for irrigating local farmland.

6.3.5 Impacts

A. Impacts to 1980

Between the present and 1980, most activity will be construction related to the opening of the first coal mine and the limestone quarry. Construction of the power plant and new town will also begin during this period.

1. Underground Mines

Although the underground coal mines are not scheduled to begin operation until 1983, construction related to the opening of the mine will be under way before 1980. This construction will have impacts on both groundwater and surface water.

The mine excavations may intersect some of the perched aquifers contained in the coal-bearing formation. As a result, the groundwater flow patterns of these aquifers will be disrupted and local springs and seeps, important as water supplies for wildlife in the area, may dry up.

2. Energy Conversion Facilities

Construction activities at both power plants will remove vegetation and disturb the soil, thus affecting surface water quality by increasing the sediment in local runoff. Additionally, the equipment used during construction will require maintenance areas and petroleum products storage facilities. Areas for the storage of other construction-related materials, such as aggregate for a concrete batch plant, will also be required. All these facilities have the potential for contaminating runoff. Control methods will be instituted at all the potential contaminant sources by channeling runoff to a holding pond for settling, reuse, and evaporation. Since the supply of water to this pond will be intermittent, most of the water may evaporate, although some may be used for dust control.

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[1] Federal Water Pollution Control Act of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

3. Municipal Facilities

From the present to 1980, most urban growth will be absorbed by existing communities, and local groundwater systems will not be significantly affected. Additional demands will be made on surface water supplies, but the overall increase should be small (see Table 6-14).

As shown in Table 6-16, wastewater flows will increase as a result of population increases from construction activities. Existing facilities at Kanab should not be overloaded by the anticipated increased wastewater flow, but unless existing wastewater treatment facilities are expanded or new facilities are built at the other towns, some surface-water pollution may result from overloads and/or bypasses.

B. Impacts to 2000

Both power plants will be constructed and in operation by 1990. In addition, ancillary activities, including coal mines and quarry operations, will be in full operation. The projected new town will also be built and occupied. These activities and facilities have several potential impacts on groundwater and surface water. No additional facilities are postulated beyond 1990; consequently, water impacts are assumed to remain the same for 1990-2000.

1. Underground Mine

As mining proceeds and mines are expanded, additional perched aquifers will be intersected. This may cause more springs and seeps to dry up. Also, some mining subsidence may occur, which could result in fractures in the overburden that may, in turn, further disrupt the flow in perched aquifers. One of the effects of this flow disruption could be the mixing of waters from fresh and saline aquifers.

The combined mining activities at both plants would consume 8,560 acre-ft/yr of water from Lake Powell which would thus not be available for other uses. Runoff during mine operation is expected to be higher than during preconstruction conditions. Mining subsidence may cause a change in surface runoff conditions, resulting in the development of new drainage patterns. This change could affect wildlife and livestock watering locations.

2. Limestone Quarry

The limestone quarries for the Kaiparowits/Escalante scenario will require 4 acre-ft/yr of water. Groundwater is assumed to be the source of these supplies, but such use may conflict with existing local water rights. Springs located near the quarries may dry up if blasting operations to open the quarries disrupt groundwater flow, and additional water sources may be affected as the quarries are operated and blasting continues. Ponds created by quarry operations may trap surface water rather than release it to surface streams in the area.

3. Power Plant

The 65-acre emergency service reservoir at each site will be lined to reduce natural pond leakage. However, some leakage will enter the groundwater system where it will recharge the local perched aquifers and provide additional water to downstream seeps and springs.

The aggregate used in construction at the Kaiparowits site will come from alluvium that is also part of the shallow aquifer in the upper Wahweap Creek Canyon. This will reduce the storage capacity of the aquifer by approximately 200 acre-ft. The removal of the aggregate should result in the formation of a pond which may discharge into Wahweap Creek. Evaporative water loss from the pond area will decrease the downstream groundwater supply. The likelihood of contamination both of the groundwater and surface water will be increased by livestock and wildlife use of the pond.

Electric generating facilities at both Kaiparowits and Escalante will cover land normally a part of the natural groundwater recharge system. About 480 acres will be removed from natural runoff contributions because of runoff control devices around critical areas and losses by catchments such as ponds. Removal of this amount of land will reduce recharge capacity by 96 acre-ft/yr, which is about 0.25 percent of the total recharge capacity in the Kaiparowits Plateau area.[1]

Fuel tanks at both sites will be surrounded by a berm designed to contain spills. In the event of a spill, fuel oil will saturate the ground within the bermed area, and the soluble fractions could eventually enter the perched aquifer system and come out in unknown concentrations in springs and seeps.

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[1] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project. 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

As noted previously, most of the water used in the project will come from Lake Powell. The two 2,000 MWe plants, their associated coal mines, and the limestone quarry will use an estimated 84,000 acre-ft/yr, an amount equivalent to about 6.8 percent of Utah's share of the Upper Colorado River allocation. Withdrawal of the water will, of course, mean that this water will no longer be available to other users in the Upper Colorado River Basin.

The removal of 84,000 acre-ft/yr of water from Lake Powell to supply the proposed plant may have a salt-concentrating effect on the Colorado River. The Bureau of Reclamation estimates that the salt increase caused by a project of similar size would be as much as 2.1 mg/ℓ at Imperial Dam. This increase would affect the agricultural users of the water through lower crop yields, causing an estimated annual loss of $230,000 per mg/ℓ of salt increase.[1] Runoff in the vicinity of the plants will increase during the construction phase, due primarily to the removal of vegetation. As noted above, runoff will decrease after construction due to structures that will retain runoff, such as the evaporative ponds.

The sediment load in local creeks will increase during the construction period. This increase will be temporary because after the plant begins operation, retention facilities at the plant sites will trap runoff and direct it into the evaporation ponds.

Some increased erosion of creek banks could occur where the water supply pipelines bridge creek beds. This impact can be avoided if banks are stabilized. Some additional creek bed erosion might occur due to increased pressure at the pipeline bridges during flood flows.

4. Effluent Disposal for Energy Facility

The evaporation ponds are used as a final disposal site for the natural salts that occur in the water supply. Concentration of salts in these ponds will be high, approximately 100,000-200,000 mg/ℓ. Thus, as these salts infiltrate through the pond liner into the groundwater system, they might, (depending on quantities and aquifer characteristics) raise the TDS content of the water, making the water unfit for humans and possibly for livestock and wildlife as well. Springs and seeps fed by this contaminated groundwater could subsequently affect surface water systems.

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[1] Utah State University, Utah Water Research Laboratory. *Colorado River Regional Assessment Study, Part I: Executive Summary, Basin Profile, and Report Digest*, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975, p. 2.

The ash disposal site will contain large concentrations of trace elements such as arsenic, barium, boron, fluorine, selenium, titanium, and vanadium. The sites are underlain by sandstone and mudstone which will greatly retard but will not stop leaking. However, the clays in the mudstone may absorb most of these trace elements before they leak into local perched aquifers.

Water leaking from the ash disposal pond could enter the surface water system by migrating laterally along the low-permeability strata to the canyon walls. As noted earlier, this water will contain trace toxic materials. The concentrations that reach the surface water are presumed small, but the transport mechanism for some of these materials through groundwater is unknown.

There will be no significant local surface-water impacts directly from plant effluents because there will be no off-site discharge of effluents. The surface-water flow volume will be reduced slightly as rainfall is trapped in the on-site waste retention ponds. Some additional flow losses will occur because of the associated runoff retention facilities.

5. Municipal Facilities

The new town will be located over a part of the recharge area of the Navajo Sandstone aquifer. Total sewage from the proposed new town will be approximately 1.22 million gallons per day. Sewer pipes to collect the raw sewage will be placed in the permeable sandstone above the aquifer, and leaks in the pipes could result in groundwater pollution. If the solid waste disposal site for the new town is placed on the recharge zone, additional pollution could take place unless special precautions are taken.

As noted earlier, under present law, effluents from the sewage treatment plant may discharge to surface waters until 1985. Effluents from the sewage treatment plant will be used in irrigated agriculture after 1985. If the treatment facility is operated properly, there should be no significant pollution from this practice.

Runoff will be increased by the construction of the new town by about 1,100 acre-ft/yr. This water will enter Wahweap Creek during storm flows and subsequently flow into Lake Powell.

Local water sources, such as springs and seeps, will be used in the construction of access roads and highways. This activity will require virtually all the water available from these sources. Highways and roads will increase runoff during storms with the increased volume likely to drain into Lake Powell.

C. Impacts after 2000

After the plants are decommissioned, the facilities will remain even though they are not operating. There will be continuing surface topographic changes due to subsidence. The land that has been temporarily reclaimed with application of water in excess of natural rainfall may lose vegetation and erode. Unless the dikes around the ponds are properly maintained, they will similarly lose their protective vegetation, will erode, and may breach as a result. Subsequently, the materials within the pond site will erode and enter the surface-water system. Although Lake Powell is the original source of the salt materials in the evaporation ponds, the eventual reentry of the salt to the lake could affect local bottom organisms if salt concentrations are sufficiently high. Similarly, the addition of trace materials and solids from the ash disposal and tailings ponds can have an adverse effect.

6.3.6 Summary of Water Impacts

The total surface water requirement for the Kaiparowits/Escalante scenario is approximately 84,000 acre-ft/yr, and the groundwater requirement for the new town and other urban and rural areas is about 12,000 acre-ft/yr. The water used by the energy facilities will be unavailable for other uses. The impact of this depletion on other users is discussed in the regional scenario, Chapter 12.

The water used for municipal supplies may be reused as irrigation water. During the lifetime of the power plants, the use of water from Lake Powell will increase downstream salinity. Ponds may leak more than expected and increase the infiltration of pollutants from the ponds to the local groundwater. The underground mining of 25.4 million tons of coal per year may likely cause unplanned subsidence, which will in turn affect surface-water drainage and may affect groundwater flow patterns.

Changes in runoff flows will occur as a result of vegetation removal, construction activities, and the facilities themselves. An increase in runoff is projected but it will vary from year to year. Conflicts may arise from the imposition of new water demands in an area with existing water rights. Changes in natural flow in springs and seeps may change watering patterns for wildlife and livestock (see Section 6.5).

The physical impacts caused by the power plants and the facilities associated with them will remain after the plants are decommissioned. At present, subsidence effects caused by the planned underground mining are irreversible. If a different mining plan were used, subsidence could be controlled or essentially eliminated. This alternative, however, is costly in terms of dollars per ton of coal delivered to the power plants.

The limestone quarry will remain at the end of operations and will likely be filled with water during some period of the year. The alternative is a costly recontouring of the quarry site.

More important is the ultimate destruction of the dikes around the evaporative holding ponds which contain the salt, ash, trace materials, sanitary sludge, and scrubber sludge. This situation could be avoided if the dikes are maintained, the contents are removed to a leakproof container, or the ponds are covered with soil and revegetated.[1] However, maintenance of the dikes will not eliminate pond leakage, and this is another potential long-term source of pollution. Pond liners will retard leakage but will not prevent it. Over the life of the plant, materials in the pond should not leach beyond the outer boundary of the liner. However, materials are likely to eventually leach through the liner and into the groundwater below.

6.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

6.4.1 Introduction

As described above, the hypothetical energy development for Kaiparowits/Escalante will occur in two counties of southern Utah: Garfield and Kane. Both counties are sparsely populated at present, but energy development will change this. Large numbers of workers, some with families, will begin to move into the area when construction of the energy facilities begins. The establishment of a new town near Glen Canyon City is part of the overall development in this scenario. The social, economic, and political impacts that can be anticipated will result either directly or indirectly from the rapid population increase that will follow.

6.4.2 Existing Conditions

Kane and Garfield Counties comprise 9,2[illegible] square miles and in 1974 had a combined population of approximately 6,600 people. This is a density of 0.7 person per square mile. Few roads serve the area, and many of these are unpaved or unimproved. No railroads or airlines presently serve the two-county area. Thus, the Kaiparowits Plateau is generally inaccessible, and any heavy

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[1] In some locations, it may be difficult to stabilize the areas that have been refilled.

TABLE 6-17: POPULATION OF KANE AND GARFIELD COUNTIES AND COUNTY SEATS, 1940-1974

Location	1940	1950	1960	1970	1974[a]
Kane County	2,561	2,299	2,667	2,421	3,300
Kanab			1,645	1,381	1,550
Other towns			737	661	700
Garfield County	5,253	4,151	3,577	3,157	3,300
Panguitch		1,435	1,318	1,318	1,350
Other towns			1,856	1,570	1,600
Two County Total	7,814	6,450	6,244	5,578	6,600

Source: Bureau of Economic and Business Research, University of Utah.

[a] Estimated.

vehicle traffic would require substantial highway improvement and construction.

Except for a recent increase, mainly in Kane County (Table 6-17), the population of the area has been static or declining for most of the past 35 years. The increase in Kane County appears to be related to the Navajo power plant just south of Glen Canyon City and may be temporary.[1]

Only the county seat of each county, Kanab in Kane County and Panguitch in Garfield County, has a population over 1,000. Both towns are located in the extreme western part of their respective counties.

Very few people actually live in the Kaiparowits Plateau portion of the two counties. In fact, in 1970 fewer than 700 people lived in Kane County outside of established towns.

Ethnically, the area is quite homogenous; there is no Black population and less than 1 percent are Indians. As is common in areas of the U.S. where population is declining, young adults have tended to leave to seek economic opportunities elsewhere.

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[1] Wistisen, M.J., and G.T. Nelson. Kaiparowits Socio-Economic Study. Provo, Utah: Brigham Young University, Center for Business and Economic Research, 1973, p. 44.

TABLE 6-18: EMPLOYMENT DISTRIBUTION IN KAIPAROWITS AREA, 1974

Industry	Kane County	Garfield County
Total Civilian Work Force	1,260	1,430
Total Employed	1,170	1,210
Agriculture	100	110
Mining	20	20
Contract Construction	15	15
Manufacturing	60	200
Transportation and Public Utilities	10	50
Wholesale and Retail Trade	200	135
Finance, Insurance, Real Estate	25	20
Service and Miscellaneous	150	190
Government	200	310
All Other Nonagriculture	310	150
Total Unemployed	90[a]	220[b]

Source: Bureau of Economic and Business Research, University of Utah.

[a] 7.1 percent.

[b] 15.4 percent.

Net outmigration from Kane and Garfield Counties between 1960 and 1970 was 1,507 people.[1]

Table 6-18 shows the distribution of employment by industry in the two counties. The local economy of the Kaiparowits area is oriented more toward tourist services and government wholesale and retail trade than is the national average. This is primarily because of tourist attractions in the area (including several national forests and parks) and a lack of major activity in other economic sectors. Agricultural activities in the area consist mainly of sheep and cattle production. Per-capita income in the two-county area remains less than 80 percent of the Utah average, (which is 82 percent of the U.S. average).[1]

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[1] Bowles, Gladys K., Calvin L. Beale, and Everett S. Lee. *Net Migration of the Population, 1960-70 by Age, Sex, and Color*. Part 6: *Western States*. Washington, D.C.: U.S. Department of Agriculture. Economic Research Service. 1975, pp. 74-75.

The Kaiparowits area was settled largely by Church of Jesus Christ of Latter Day Saints (Mormon) immigrants from other parts of Utah. Mormons still constitute the single largest religious group in the area.[2]

Residents of the area are apparently overwhelmingly in favor of energy development. Southern Utah has lagged behind the rest of the state economically, and residents would like an opportunity to catch up, which is what energy development in this area seems to offer.[3] Further, economic opportunities would both help keep the young people from leaving southern Utah and allow relatives and friends to return.

Both Kane and Garfield Counties are governed by three-member boards of commissioners. Governmental services in these counties are limited; law enforcement is provided by two full-time law officers in each county. Both counties are served by joint city/county volunteer fire departments. Kane County has a planning commission, but Garfield County does not. Both counties have a master plan and, although only Kane County currently has a zoning ordinance, one is being drafted for Garfield County. Public education is provided by a single school district in each county. Public health services in Kane County include maintenance of a 31-bed hospital in Kanab; a 28-bed county hospital is now under construction in Panguitch to replace the old 16-bed facility there. Doctors are not available elsewhere in the two counties.

Panguitch is governed by a mayor and five councilmen. Two full-time policemen provide law enforcement, and the joint city/county volunteer fire department provides fire protection. Currently, the city has neither a professional city engineer nor a planner. However, the city owns and operates a water system and has a zoning ordinance.

Kanab, seat of Kane County government, has a mayor and five councilmen. It employs three full-time policemen and, like Panguitch, participates in a joint volunteer fire department arrangement with the county. Unlike Panguitch, Kanab has a licensed city engineer. It does not have a professional planner, but the city does have a zoning ordinance. Kanab has both a city-owned and operated water and sewage treatment system; an expansion of the water system is now under way. The other incorporated communities in the two counties have no municipal water or sewer systems.

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[1] Kiholm, Janet. "Personal Income in Utah 1970-1975," Utah Economic and Business Review, Vol. 36 (June 1976), pp. 1-6.

[2] Dotson, John L. "Dust in the Sun." Newsweek (October 27, 1975), p. 10.

[3] See U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, pp. A-710 to A-726.

Overall, Kane and Garfield Counties and the two small towns of Kanab and Panguitch appear to lack the resources necessary to deal effectively with energy development in the area. However, the counties have been attempting to upgrade their capabilities, particularly in planning. Both counties and their county seats participate in Utah's system for intergovernmental planning cooperation.[1] They also participate in the Kaiparowits Planning and Development Advisory Council, which Governor Calvin L. Rampton established by executive order in August 1974.[2] The council was established to guide and coordinate activities related to energy development in Kane and Garfield Counties.

6.4.3 Population Impacts

Most of the social, economic, and political impacts in the Kaiparowits/Escalante scenario will result from population increases, initially during construction and later during operation of the facilities.

Construction of the first power plant was to have begun in 1975 and will extend into 1983. The employment projections used are shown in Table 6-19. The two scenario facilities are shown separately because of their differing impacts. Population changes were projected using economic base analysis, employment multipliers (which increase from 0.2 to 0.4 for construction and from 0.2 to 0.5 during operation of the facilities), and the employment data in Table 6-19. Population/employee multipliers of 2.2 for construction and 3.0 for operation were assumed. An average of 80 percent of the new employees in the area were assumed to be from outside the local area, a figure which may be high early in the development but which should be a reasonable average.[3]

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[1] This system is described in 6.4.8.

[2] The executive order is reprinted in U.S., Department of the Interior, Bureau of Land Management, *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, pp. A-259 to A-260.

[3] The multipliers used here are aggregates intended to include a variety of factors, including local labor recruitment.

TABLE 6-19: CONSTRUCTION AND OPERATION EMPLOYMENT FOR KAIPAROWITS SCENARIO, 1975-2000[a]

Year	Facility #1 (Kaiparowits Site)		Facility #2 (Escalante Site)	
	Construction	Operation	Construction	Operation
1975	40			
1976	440			
1977	1,060			
1978	1,670			
1979	2,570	0	0	
1980	3,360	430	40	
1981	2,560	740	440	
1982	830	1,480	1,060	
1983	0	2,970	1,670	0
1984		2,970	2,570	430
1985		2,970	3,360	740
1986		2,970	2,560	1,480
1987		2,970	830	2,970
1988		2,970	0	2,970
1989 to 2000		2,970		2,970

Source: Carasso, M., *et al.* *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

[a] About 20-25 percent of construction and 80 percent of operation employment is attributable to the coal mining activity alone.

A community choice model based on a town's population and distance from facility sites was used to allocate populations to towns in the Kaiparowits/Escalante area.[1] The assumed new town was allocated 300 people *a priori* in 1977 and 1978, after which its population changes also were subject to the model. The new town is assumed to be a new incorporated community rather than a company town.

Population estimates in this scenario indicate that Page, Arizona will attract the majority of the growth early in the development. Established schools and services in Page will

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[1] Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 90-97. A friction of distance factor of 1.5 was used.

TABLE 6-20: POPULATION ESTIMATES FOR PAGE AND COMMUNITIES IN KANE COUNTY, 1975-2000

Year	Page, Arizona[b]	Kane County, Utah				
		Kanab	New Town	Glen Canyon City	Others	Total
1975	6,000	1,550	0	20	1,730	3,300
1976	5,820	1,660	0	25	1,745	3,430
1977	7,020	1,810	500	40	1,760	4,110
1978	7,850	1,910	1,250	60	1,780	5,000
1979	8,980	2,040	2,000	80	1,790	5,910
1980	10,440	2,200	3,350	110	1,800	7,460
1981	10,270	2,200	3,740	110	1,810	7,860
1982	9,660	2,150	3,910	100	1,820	7,980
1983	10,770	2,270	6,240	140	1,830	10,480
1984	11,100	2,340	6,500	150	1,840	10,830
1985	11,310	2,380	6,670	150	1,850	11,050
1986	11,430	2,410	6,750	150	1,860	11,170
1987	11,580	2,440	6,850	150	1,870	11,310
1988	11,590	2,440	6,830	150	1,880	11,300
1989	11,690	2,460	6,890	150	1,890	11,390
1990	11,780	2,480	6,940	150	1,910	11,480
1995	12,070	2,540	7,120	160	1,960	11,780
2000	12,370	2,600	7,290	160	2,010	12,060

[a] Natural increases of 0.8 percent annually through 1990 and 0.5 percent annually thereafter are incorporated. Given the scenario and data assumptions, the estimates in the table are within about 25 percent of conditions which could be expected.

[b] Page estimates include a decline from population associated with the Navajo power plant of 2,000 during 1975 and 1,000 during 1976.

attract many people, especially families with children. A 75-percent increase in size (to 10,440) is expected by 1980, after which only minor population changes should occur (Table 6-20). Kane County is expected to triple in population by 1983, after which growth will be gradual. Much of the increase should take place in the new town, where 2,000 will live by 1979 and 6,500 by 1984. Kanab can expect a 40-percent increase by 1980; roadside sprawl of trailer homes is likely in the Glen Canyon City area, where the present population of about 20 will grow to 110 by 1980.

Garfield County will receive only minor impacts from the first mine and power plant development located to the south. However, after construction begins near Escalante in 1980, population will rise considerably. Between 1980 and 1985, when construction is completed, a 240-percent increase in county population is expected, most of it at Escalante (11,000 population in 1987) but much of it in and around the small towns along Utah Highway 12 (Table 6-21).

Age-sex distributions of population were estimated from 1970 data for Kane and Garfield Counties and age distributions of employees and family members from recent surveys in the West.[1] Page, Arizona was assumed to have a structure similar to southern Utah. As is typical, the relative number of males is expected to be greatest during construction (1980-1985), and the proportion of population in the 20-35 age group remains higher due to employment opportunities (Table 6-22).

6.4.4 Housing and School Impacts

Housing and school enrollment impacts are obtained from population and age structure estimates, assuming the age structure is the same throughout the area. The 6-13 age group is classified as elementary school age and the 14-16 age group is classified as secondary school age,[2] providing estimates with perhaps 25-percent possible error, given the population estimates. Housing demand is estimated from the proportion of the population which is male and 20 years of age and older.

Estimates of housing demand are generally high during construction and continue to rise slowly through 2000 (Table 6-23). By 1980 in this scenario, Kane County will need over 1,700 new homes, 1,200 at the new town site alone (Figure 6-6). Judging from other western energy development sites, at least half of these could be mobile homes.[3] Garfield County is even more likely to have a large number of mobile homes, since the demand for housing in 1985 will be nearly five times the 1975 level (Figure 6-7). Escalante is the probable site for extensive mobile home location. Likewise, the expected growth of the very small towns in the area (Tables 6-20 and 6-21) will largely be accommodated by mobile homes.

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[1] Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 31-39.

[2] These assumptions and their resulting estimates are associated with perhaps a ±25-percent error given the population estimates.

[3] Mountain West Research. *Construction Worker Profile*, p. 103.

TABLE 6-32: POPULATION ESTIMATES FOR COMMUNITIES IN GARFIELD COUNTY, 1975-2000[a]

Year	Escalante	Cannonville	Tropic	Henrieville	Panguitch	Boulder	Other	Total
1975	650	110	330	150	1,370	90	600	3,300
1976	680	120	370	160	1,420	90	600	3,440
1977	750	150	430	190	1,520	100	610	3,750
1978	790	170	470	210	1,590	100	610	3,940
1979	840	190	530	240	1,670	110	620	4,200
1980	900	236	610	270	1,770	119	620	4,510
1981	1,390	230	640	280	1,800	120	630	5,090
1982	2,270	230	640	290	1,800	130	640	6,000
1983	3,300	270	720	330	1,910	140	640	7,310
1984	6,040	290	790	360	1,940	160	650	10,230
1985	8,600	310	820	380	2,000	170	650	12,930
1986	9,400	320	840	390	2,020	170	660	13,800
1987	11,000	320	860	400	2,050	180	660	15,470
1988	9,570	330	850	400	2,040	170	670	14,030
1989	9,660	320	850	400	2,060	170	670	14,130
1990	9,730	330	860	400	2,080	170	680	14,250
1995	9,980	330	880	410	2,130	180	700	14,610
2000	10,200	340	900	420	2,180	180	720	14,940

[a] Natural increases of 0.8 percent annually through 1990 and 0.5 percent annually thereafter are incorporated. Given the scenario and data assumptions, the estimates in the table are within about 25 percent of likely conditions.

TABLE 6-22: AGE-SEX DISTRIBUTION FOR PAGE AND KANE AND GARFIELD COUNTIES

Age Group	1975	1980	1985	1990-2000
Female				
65 and over	.048	.020	.013	.013
55-64	.051	.034	.025	.021
35-54	.110	.102	.092	.085
25-34	.053	.127	.151	.156
20-24	.024	.045	.045	.042
17-19	.024	.029	.030	.029
14-16	.042	.023	.021	.024
6-13	.098	.061	.065	.074
0-5	.053	.041	.049	.057
Total	.503	.483	.491	.501
Male				
65 and over	.050	.021	.014	.013
55-64	.054	.038	.027	.022
35-54	.104	.110	.096	.084
25-34	.048	.140	.158	.155
20-24	.019	.049	.048	.041
17-19	.026	.033	.032	.029
14-16	.041	.022	.021	.023
6-13	.100	.062	.065	.074
0-5	.056	.042	.050	.058
Total	.498	.517	.509	.499

TABLE 6-23: ESTIMATED HOUSING DEMAND IN KANE AND GARFIELD COUNTIES AND PAGE, 1975-2000

Location	1975	1980	1985	1990	2000
Kane County	910	2,670	3,790	3,620	3,800
New Town	0	1,200	2,290	2,190	2,300
Page	1,650	3,740	3,880	3,710	3,900
Garfield County	910	1,610	4,430	4,490	4,710
Escalante	180	320	2,950	3,060	3,210

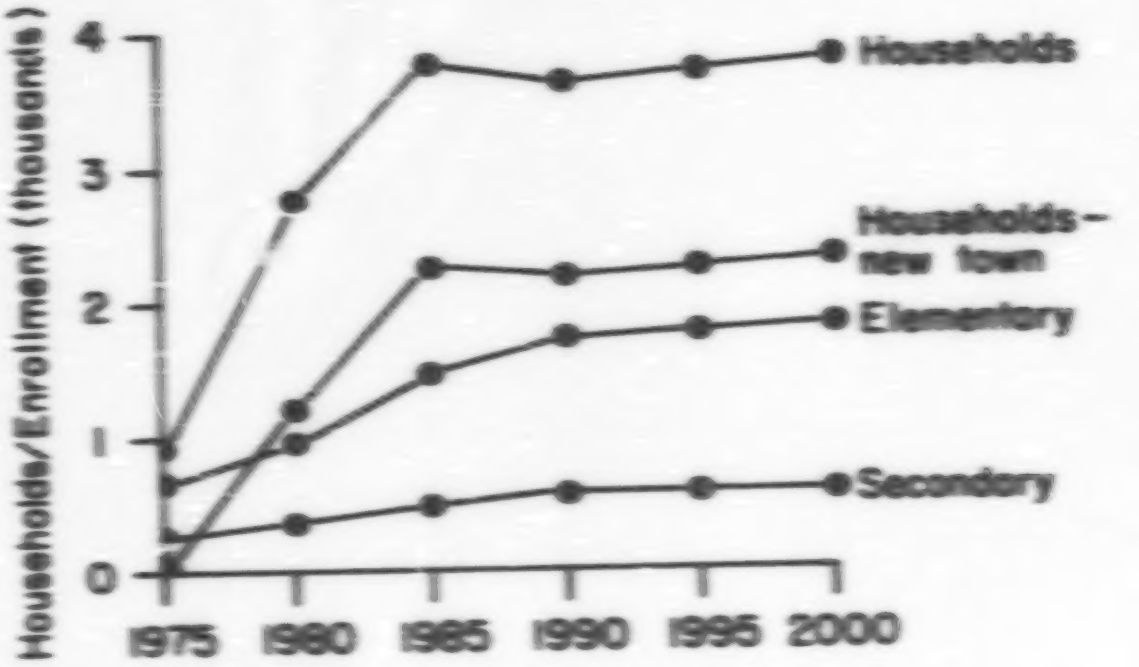

FIGURE 6-6: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN WAKE COUNTY, 1975-2000

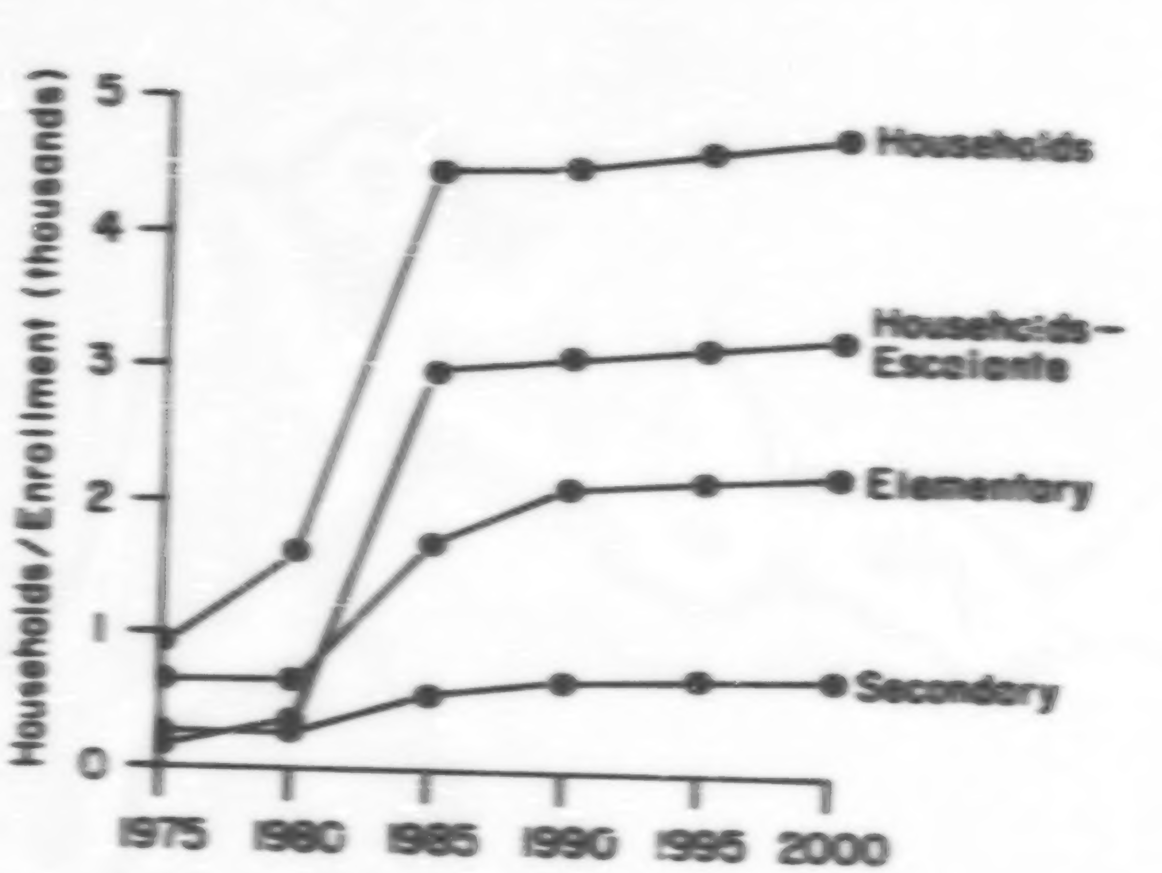

FIGURE 6-7: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD COUNTY, 1980-2000

TABLE 6-24: ESTIMATED SCHOOL ENROLLMENT IN KANE AND GARFIELD COUNTIES AND PAGE

School	1975	1980	1985	1990	2000
Elementary					
Kane County	650	920	1,440	1,700	1,780
Page	1,190	1,280	1,470	1,740	1,830
Garfield County	650	650	1,680	2,100	2,200
Secondary					
Kane County	270	340	460	540	570
Page	500	500	500	530	580
Garfield County	270	270	540	670	700

School enrollment projections in Table 6-24 are rather low until the 1980's because short-term construction personnel do not all bring families and because many of those who do bring children will probably choose to live in Page, which balances the enrollment decline after completion of the Navajo power plant. Still, when the increased enrollment from Kaiparowits area impacts is balanced with the decline in population and enrollment from Navajo power plant, a net increase of only about 300 students by 1985 and 600 by 1990 is expected in Page.

The impact of this approximate 30-percent increase in enrollment by 1985 on Page will be relatively slight compared to the impacts anticipated in Kane and Garfield Counties (Figure 6-8). The enrollment increase in these two counties will be more than 100 percent by 1990. Further, this increase will occur in a part of the area where, except for Escalante, school facilities are not currently available. The financial impacts associated with providing education for this increased school-age population will be felt primarily in Garfield County (Table 6-25), although the lead time is somewhat longer there than for Kane County. Overall, about $14 million will be needed for schools in southern Utah because of the energy development and about $2.7 million in Page.

6.4.5 Land Use Impacts

Overall land area needed for the two facilities will be relatively small but must be taken from the few suitable sites in the scenario area. The energy facilities would occupy less than 20 square miles, about the same as expected urban development in the two-county area. The overall impact would amount to 0.4 percent of the area of the two counties but considerably more of the usable land area.

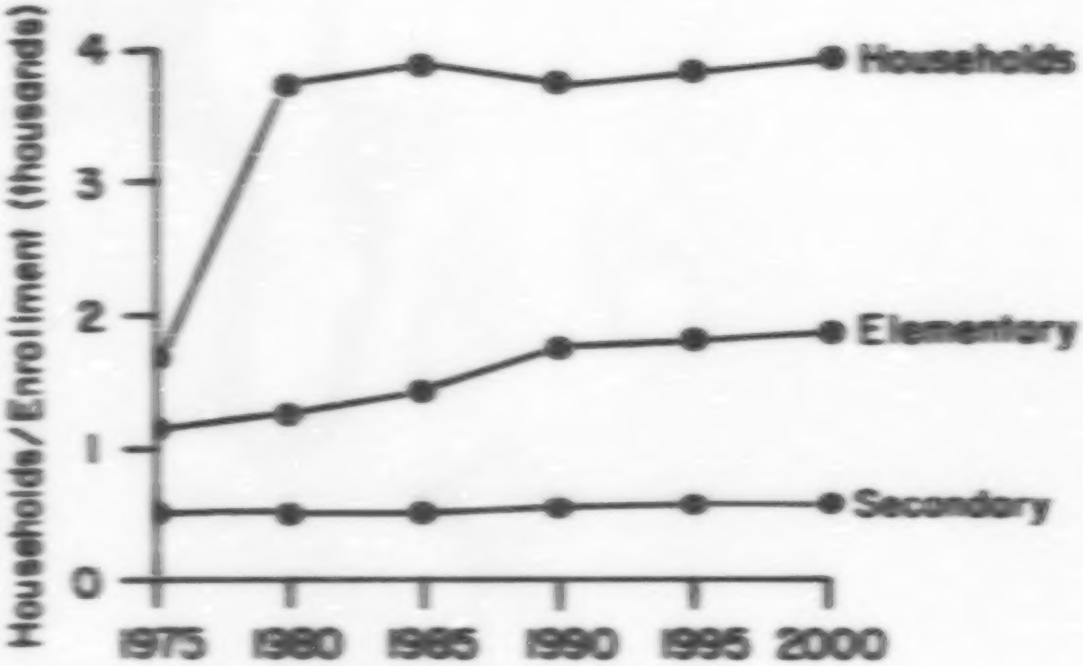

FIGURE 6-8: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN [illegible], 1980-2000

TABLE 6-25: FINANCE PROSPECTS FOR KANE AND GARFIELD COUNTIES AND PAGE SCHOOL DISTRICTS, 1975-2000

Location	Year	Estimated Enrollment	Classrooms At 21/Room	Capital Expenditure Required (millions of dollars)[a]	Operating Expenditure Required (millions of dollars)[b]
Kane County	1975	920	44[c]		1.2
	1980	1,260	60	0.8	1.6
	1985	1,890	90	2.4	2.5
	1990	2,240	107	3.3	2.9
	2000	2,350	112	3.6	3.1
Garfield County	1975	920	44[c]		1.2
	1980	920	44	0	1.2
	1985	2,220	106	3.2	2.9
	1990	2,770	132	4.6	3.6
	2000	2,900	138	5	3.7
Page	1975	1,690	80[c]		2.2
	1980	1,780	85	0.2	2.3
	1985	1,970	94	0.7	2.5
	1990	2,290	109	1.5	3
	2000	2,420	115	1.8	3.1

[a] Cumulative, based on $2,500 per pupil space. See Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971.

[b] Each year, based on current average of about $1,300 per pupil. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[c] Estimated.

Larger land use impacts may result from recreational pressure on the land in Kane and Garfield Counties. The eastern part of the two counties is virtually uninhabited at present. Details of the impact of increased recreation uses in this area are discussed in Section 6.5.

6.4.6 Economic and Fiscal Impacts

A. Economic

One of the most immediate local impacts from energy development in the Kaiparowits/Escalante area will be a change in income distribution both because energy and construction workers tend to earn relatively high incomes and because local residents will be able to find employment in energy development or to establish retail businesses in the area. The income impact will be especially noticeable in southern Utah, where, the per capita income is currently less than 70 percent of the national average.[1]

In making the income distribution projections, the patterns recently found in currently affected energy resource communities in the West were adopted.[2] The construction phase results in a 43-percent rise in median household income by 1985, including increased incomes for many long-time residents. This declines by 1990 but will remain 24 percent above current levels (Table 6-26 and Figures 6-9 and 6-10). The principal changes in the Kane and Garfield County income distribution will be a large relative decrease in low-income families and a predominance of families in the $15,000-25,000 income range.

A second major impact will be an expansion in secondary employment, especially retailing. Any necessary industrial services are likely to be either provided within the mine-power plant complexes or imported from outside the Kaiparowits area. No other major industrial facilities are expected in the area from this scenario. Substantial increases in service employment to provide goods and services for the local population will be part of the overall impact of energy development. Because retail activities are market-oriented, their location is largely determined by the locations of customers and other businesses. Therefore, much of the early impact, at least through 1980, will occur

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[1] U.S., Department of Commerce, Bureau of Economic Analysis, "Local Area Personal Income," Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75; Kilholm, Janet. "Personal Income in Utah 1970-1975", Utah Economic and Business Review, Vol. 36 (June 1976), pp. 1-6.

[2] Mountain West Research, Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50.

TABLE 6-26: PROJECTED INCOME DISTRIBUTION FOR KANE AND GARFIELD COUNTIES, 1975-2000
(Proportion of households in income categories)

	Annual Income (1975 Dollars)								
Year	Less than 4,000	4,000 to 5,999	6,000 to 7,999	8,000 to 9,999	10,000 to 11,999	12,000 to 14,999	15,000 to 24,999	25,000 and over	Median Household Income
1975	.163	.075	.084	.111	.121	.123	.246	.076	11,100
1980	.091	.046	.048	.077	.102	.119	.396	.121	15,030
1985	.065	.043	.040	.078	.106	.129	.438	.102	15,900
1990	.076	.051	.089	.092	.114	.132	.383	.063	13,800
1995	.076	.051	.088	.091	.114	.132	.383	.064	13,800
2000	.076	.051	.088	.091	.114	.132	.383	.064	13,800

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. *Household Income in 1969 for States, SMSA's, Cities, and Counties: 1970*. Washington, D.C.: Government Printing Office, 1973, and inflated to 1975 dollars. Income distributions for construction, operation, and service workers are from Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that "other newcomers" are operation employees and that new service worker households have the same income distribution as long-time residents.

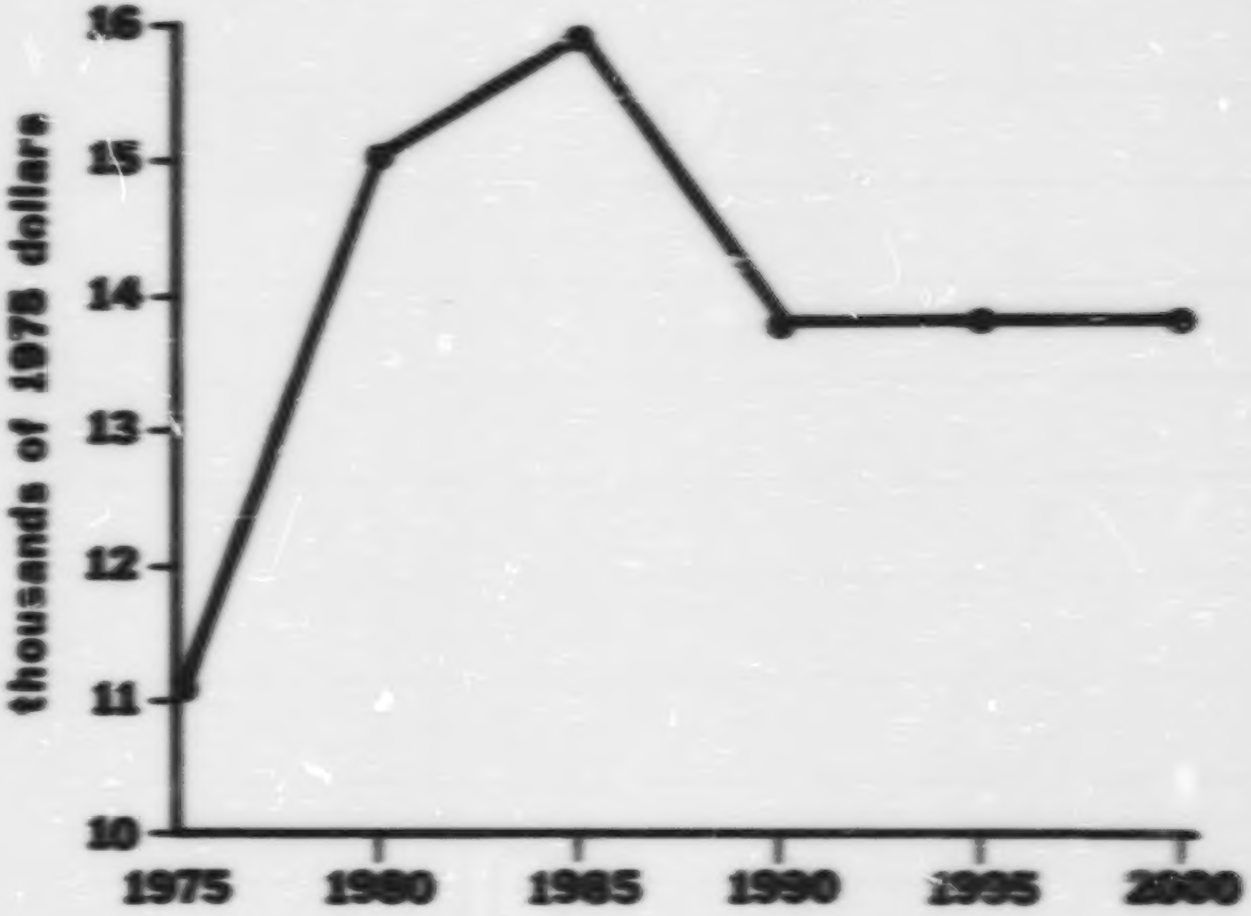

FIGURE 6-9: MEDIAN FAMILY INCOME, KANE AND GARFIELD COUNTIES, 1975-2000

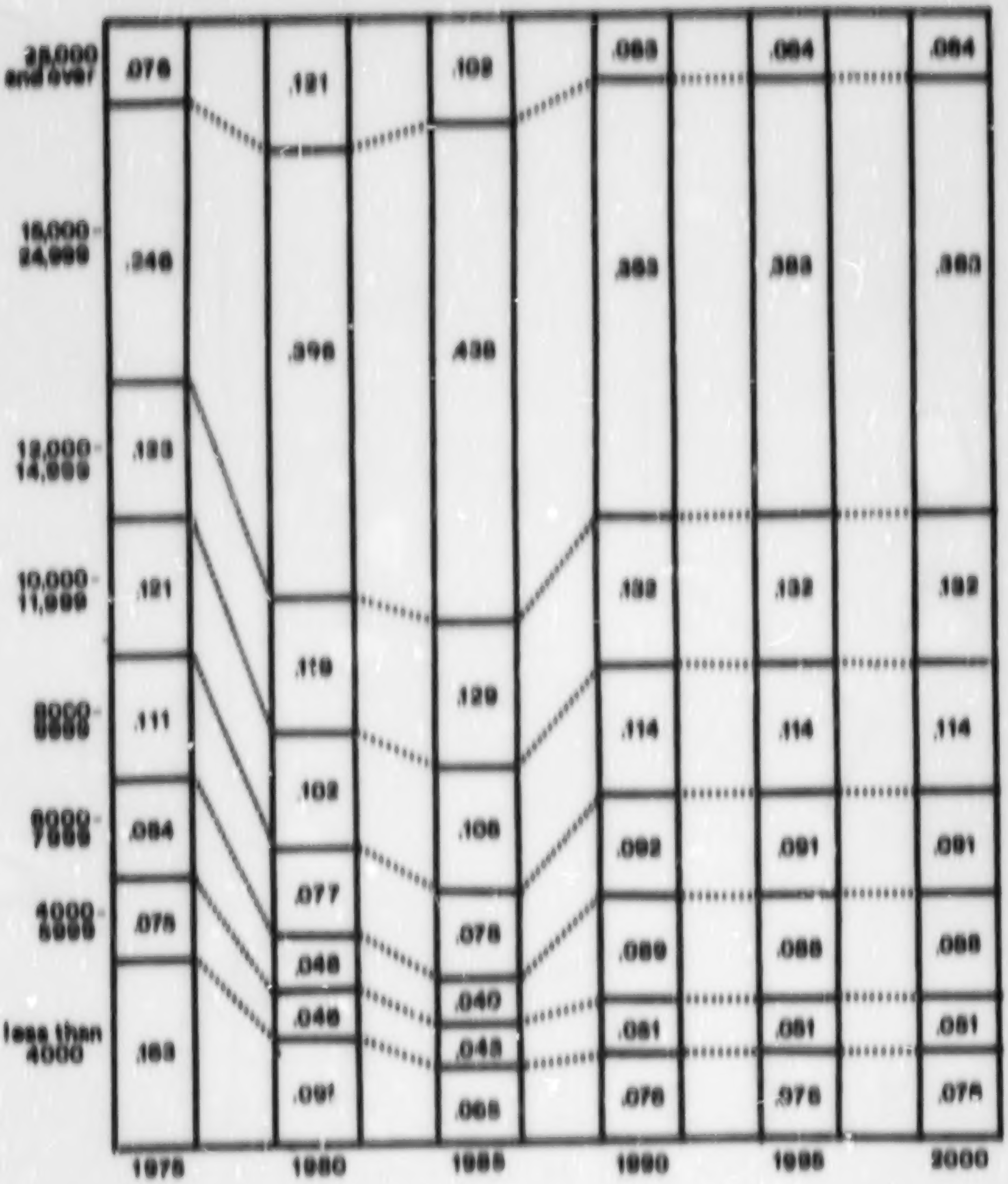

FIGURE 6-10: ESTIMATED INCOME DISTRIBUTION FOR KANE AND GARFIELD COUNTIES, 1975-2000

at Page, where most energy workers will live and where businesses are already serving Navajo power plant workers and their families. However, much of the 1975-1980 impact on Page from Kaiparowits will have the effect of offsetting an economic decline during the phase-out of construction at the Navajo facility. Because of Page's current mix of goods and services and its importance to the southern Utah area before the Kaiparowits new town is built, a 75-percent increase in retail activity (based on the expected population increase) at Page is expected by 1990.

The Kaiparowits new town and, to a lesser extent Escalante, will provide lower order (frequently purchased, often lower cost) goods and services, while higher order retail activities will be relatively more numerous at Page and, to some extent, Flagstaff. Activities in the Kaiparowits/Escalante area towns by the mid-1980's are likely to include a bank, taverns, gas stations, food stores, restaurants, laundries, and probably clothing stores. However, no large-scale economic benefit to the Page and southern Utah area is likely to result because the goods purchased there will largely be manufactured and wholesaled outside the area. Flagstaff, Arizona, a rapidly growing city about 120 miles south of Page, is likely to benefit from increased wholesale activity. Salt Lake City and Phoenix should also benefit from increased wholesale and retail activity as well as from state sales and income tax receipts.

Local government expenditures will generally be manageable except for Escalante. The Kaiparowits new town could plan to meet public expenditure demands by including the energy facilities in the Special Service Districts.[1] Page already has the Navajo power plant in its property tax base, and has excess capacity in most of its public services. The new town's construction presumably would include sufficient capital facilities to handle all the expected population. Escalante, by means of Special Service Districts, also could use energy facility tax revenues but might have more trouble than other towns in having ready capital in time for the demand. This is discussed further in the section on fiscal impacts. In the view of some persons, the new roads, pipelines, transmission lines, and reduced visibility in the wilderness areas would also downgrade the scenic attractions of the area,[1] having serious implications for a region which is currently dependent on tourism for its economic livelihood.

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[1] Special Service Districts in Utah can supply water, sewage, drainage, flood control, garbage, hospital, transportation, recreation, and fire protection services. They may include several noncontiguous areas, such as a power plant and a town separated by several miles, and may cross jurisdictional boundaries. See Section 6.4.8.

Agriculture involves about 660 square miles in Kane and Garfield Counties (about 7 percent of the area), down from 740 square miles in 1967. Eight percent of the labor force works in agriculture, mainly cattle and sheep grazing operations. Little ranching takes place near the scenario facility sites, and it is unlikely that energy development would adversely affect agriculture. The amount of land now committed to national forest and other federal uses also indicates that not much increase in agriculture is likely in southern Utah. Smaller ranches will gradually go out of production or be consolidated into larger units, but this is a national trend not expected to be influenced by energy development.

Finally, the energy-related economic activity will result in inflation in local housing and labor markets, perhaps equal to the short-term increase in income. Project workers will be able to outbid long-time local residents for land (where private land is available) and for goods and services; some low-wage service workers will be attracted away from their present jobs. Some employees of existing businesses in the area can be expected to move to higher paying jobs in the energy facilities.

B. Fiscal

The largest fiscal impact of the energy development hypothesized in this scenario will arise from property taxes. Development expenditures are estimated to be $983 million for the power plant and $216 million for related coal mines at each site. This is equivalent to 20 percent of the currently assessed valuation in all of Utah.

Assuming that the current mill levy rates are maintained[2] and that the energy facilities are taxable at those levels, the

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[1] See Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity." Audubon Magazine, Vol. 78 (Spring 1976), pp. 64-90; Ives, Berry, and William Schulze. Boomtown Impacts of Energy Development in the Lake Powell Region, Draft Lake Powell Research Project Bulletin. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1976.

[2] Current levies are 1.82 percent of full cash value in Kane County and 1.68 percent in Garfield County (University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976, Tables VII-16 and VII-17).

TABLE 6-27: PROPERTY TAX REVENUES
(millions of 1975 dollars)

Jurisdiction	1977	1980	1985	1990
Kane County[a]	3.8	15.6	21.8	21.8
Garfield County[b]	0	1	18.3	21.9
Escalante[b]	0	.01	.42	.48
Coconino County, Arizona[b]	.03	.14	.17	.18

[a] Tax on energy facilities.

[b] Tax on residential and commercial development.

energy facilities and related residential and commercial development will generate the property tax revenues shown in Table 6-27.

Only about 3 percent of the increased tax base in the area will be accounted for by residential and commercial development. All property taxes in Utah currently go to county and local governments. On the average, school districts get 59.8 percent.[1]

By law, property tax will be due on both mine structures and equipment (as calculated above) and on the coal resource when mined. However, nonmetallic mines located on land leased from public agencies have not been subjected to this "privilege tax" in the past. Because of this precedent, and the heretofore arbitrary application of taxes to other mineral deposits, no potential revenues are assumed from this source.[2]

Utah will derive some benefit from federal royalties. According to recently passed legislation, 12.5 percent of mine-mouth value has been set as a target for royalty collection, and of this amount 50 percent will be returned to the state.[3] (A portion of the state's share must be expended in the coal-impact area, but we have credited all of it to the state's account.)

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[1] University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976, Table VII-14.

[2] Bronder, Leonard D. Taxation of Coal Mining: Review with Recommendations. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976, appendix on Utah.

[3] Bureau of National Affairs. Energy Users' Report. Current Developments No. 129 (January 29, 1976), pp. A-3 through A-4.

TABLE 6-28: ALLOCATION OF FEDERAL COAL ROYALTIES (millions of dollars)

Fund	1980	1985	1990	2000
State	1.8	10.2	18.3	22.2
Reclamation	1.5	8.1	14.7	17.8
Total (including others)	3.7	20.3	36.7	44.5

Using coal prices derived from the nominal case run of the SRI model[1] (rising from $7.99/ton in 1975 to $13.71/ton by 2000, in constant dollars), and assuming that all of the coal is obtained through federal leases,[2] royalties may be expected as in Table 6-28.

Excise taxes will apply both directly to the energy facilities (a use tax on building materials, whether imported to the state or bought locally) and indirectly (sales tax on the workers' retail purchases). Construction activity will reach a peak in 1980, when $337 million of materials and equipment are installed. At a rate of 4 percent, Utah would gain $13.5 million in use tax revenue that year, and the counties would gain $1.7 million (at a 0.5-percent rate). After the completion of the energy facilities, only the sales tax would continue. The $46 million/year of retail sales[3] would yield $1.4 million for the state of Utah, $50,000 for Page, etc. These revenues are detailed in Table 6-29. Note that Page will not collect a use tax from the plants, only a sales tax from retail activity.

As a final source of revenue, localities can charge for basic services, most notably water and sewer. Taking the Utah

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[1] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] 87 percent of the land in these counties is federally owned.

[3] Assuming that 56.0 percent of new personal income goes to taxable purchases. This is the average rate for the mountain states. See U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Tables 1317 and 629.

TABLE 6-29: REVENUE FROM SALES AND USE TAXES[a] (millions of 1975 dollars)

Location	1977	1980	1985	1990
Utah				
State	4.1	14.2	11.3	1.4
Kane County	.51	1.52	.11	.08
Garfield County	.01	.26	1.3	.1
Arizona				
State	.12	.38	.59	.43
Page	.02	.07	.07	.05

[a] Distribution of retail sales assumed proportional to population.

average of $74.80 per capita for charges and miscellaneous fees by local government.[1] additional local revenues can be expected as shown in Table 6-30.

All the revenues cited in the preceding analysis are grouped by jurisdiction in Table 6-31 to provide a basis for comparison with expenditures.

As stated earlier, energy development will necessitate an expansion of public services, especially in the areas of education and water and sewage treatment, and thus will require substantial expenditures. In analyzing these requirements, standard

TABLE 6-30: GOVERNMENT FEES FOR SERVICES (millions of 1975 dollars)

County	1977	1980	1985	1990
Kane County	.06	.31	.58	.61
Escalante, Utah	.01	.02	.59	.68
Coconino, Arizona	.07	.32	.39	.42

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[1] Inferred from University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976, Table VII-8.

TABLE 6-31: SUMMARY OF REVENUES FROM ENERGY DEVELOPMENT
(millions of 1975 dollars)

Location	1977	1980	1985	1990
Utah State[a]	6.1	20	33.6	26.1
Kane County	1.7	8.1	9.5	9.5
Kane School District	1.7	9.3	13	13
Garfield County	0	.6	8.6	8.8
Garfield School District	0	.6	10.9	13
Escalante	.03	.05	1.14	1.26
Arizona State	.12	.58	.59	.43
Arizona Local	.12	.53	.63	.65

[a] Including funds for discretionary allocation to local units.

accounting procedures were followed; capital and operating expenditures were identified separately. It was assumed, as stated previously, that $2,500 in capital costs will be incurred for each additional student. (School enrollment is the only substantial growth category foreseen in the decade of the 1990's, either in expenditures or revenues.) Other likely capital expenditures include $1,760 per capita for water and sewage facilities, and $590 for other items[1] (mostly hospitals and parks). Table 6-32 shows the projected capital requirements of Kane and Garfield Counties resulting from the application of these figures to the appropriate population projections, by 5-year periods.

For operating expenditures, it is assumed that Utah averages will be maintained.[2] The annual rates are projected in Table 6-33.

A comparison of these requirements with the previously tabulated revenue projections shows that Utah and many of its local jurisdictions will enjoy substantial, positive fiscal

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[1] THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974

[2] At $1,300 per year per student for schools, $197 per capita for other local functions, and $645 for state government. See University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976.

TABLE 6-32: CAPITAL REQUIREMENTS OF LOCAL GOVERNMENTS BY QUINQUENNIA
(millions of 1975 dollars)

Location	1976 to 1980	1981 to 1985	1986 to 1990	1991 to 2000
Kane County	9.8	8.4	1	NA
Kane School District	.8	1.6	.8	.3
Garfield School District	0	3.2	1.4	.3
Escalante, Utah	.59	10.1	2.66	NA
Page, Arizona[a]	10.64	2.53	1.9	NA

NA = not applicable, since no appreciable population increase.

[a] General government and schools.

benefits by 1980 if current tax rates are mainvained. For example, the Kane School District would receive additional property tax revenues of $13.0 million/year by 1982, while only $1.7 million/year in additional operating funds would be needed, even by 1990. The surplus will leave more than enough for the $3.2 million in capital to be accumulated over the first 15 years. Similar circumstances await the county governments. The state government will eventually collect about twice as much as is needed for additional services ($26.1 million/year versus $12.3 million in 1990 and beyond). In fact, the disparity is even greater in the mid-1980's, when some $11 million/year will be realized from the use tax on construction materials.

TABLE 6-33: INCREASES IN OPERATING EXPENDITURES OF SELECTED LEVELS OF GOVERNMENT
(millions of 1975 dollars)

Jurisdiction	1977	1980	1982	1985	1990
Utah State	.80	3.5	4.8	11.2	12.3
Kane County	.16	.82	.92	1.53	1.61
Kane School District	.18	.44	.77	1.27	1.72
Garfield School District	0	0	.68	1.69	2.4
Escalante, Utah	.02	.05	.32	1.57	1.79
Page, Arizona[a]	.25	.99	.94	1.41	1.92

[a] General government and schools.

Municipalities, however, will experience negative fiscal impacts if higher levels of government do not subsidize them. Escalante and Page may be taken as examples of this problem. Escalante's new revenues will just about keep pace with operating expenditures until the mid-1980's, but later deficits will grow to about $530,000 per year ($1.79 million new expenditures versus $1.26 million new revenues). Moreover, Escalante must build new facilities at a rate of $3.62 million/year during 1981-1985 if the current quality of service is to be maintained. Fortunately, the capital requirements will tail off to $.53 million/year in the late 1980's, and a negligible level thereafter, due to a leveling off of population growth.

Similarly, in Page, Arizona, operating deficits will widen continually, from $.46 million in 1980 to $.78 million in 1985 and $1.27 million in 1990.[1] Capital requirements will peak at $2.13 million/year in the late 1970's, coming down to about $.45 million through the 1980's.

The disparities between state, county, and municipality revenues arise because the former units can tax energy developers directly but the latter can tax only the new population. Counties levy property taxes and use taxes on the facilities; the state gets a share of federal coal royalties, the larger part of sales and use taxes, and an income tax. Thus, their revenues can grow faster than population (and hence costs) without any change in tax rates. However, as long as municipalities rely on population-determined taxes (residential property, utility fees, retail sales), they cannot expand revenues faster than population without raising their rates.

6.4.7 Social and Cultural Impacts

The major sociocultural impact resulting from the Kaiparowits/Escalante development will be a drastic alteration of the dominant lifestyle in the area. At present, communities are small, relatively isolated, and inhabited by persons who have established rural traditions[2] and strong religious beliefs. Residents of the communities are family and extended family oriented. The influx of individuals with different geographical, cultural, and religious origins, higher incomes, and a somewhat more urban perspective will provide a sharp contrast to the present population. Because these new residents will eventually outnumber the present population, changes in the dominant lifestyle will occur.

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[1] Deficits include both school and general local government.

[2] Minar, David W., and Scott Greer. The Concept of Community: Readings with Interpretations. Chicago, Ill.: Aldine, 1969.

Religious and value differences could also be problems. The inhabitants of southern Utah are almost exclusively Mormon, whereas a large number of the immigrants will probably not be. Mormon standards may conflict with immigrant preferences, particularly with regard to intoxicants and smoking, and conflicts from these differences may well arise for immigrant school children. In addition, the evangelistic posture of the Mormon church could have an effect by generating both converts and conflicts. The lack of alternative churches in Utah may make Page a worship center because eight denominations, in addition to the Latter Day Saints, have congregations there.

Dissatisfactions with mobile home living and insufficient social services will produce impacts such as high divorce rates and other indications of community and family stress.[1] One aspect of this mentioned above will be an increased crime rate. However, after construction activity is completed (by 1988), these local problems should decrease significantly.

Although community medical facilities appear capable of meeting projected needs to 1985, adequate medical personnel will be hard to retain because doctors generally are reluctant to live in isolated, nonmetropolitan areas. The two Utah counties will need 39 doctors by 1990 to meet the national average of one doctor per 660 population; to even maintain the current average of one doctor per 1,320 population will require 14 physicians more than the five who currently practice there.

Because the population increases in the area will be caused primarily by the energy development activities, a number of "company town" characteristics may develop in area communities. Work schedules, holidays, and vacations might well determine the hours for businesses in these communities, creating an impression of company domination. Company-owned buildings and vehicles will also contribute to this impression, creating resentment among some native residents. The new town near Glen Canyon City will probably show the greatest "company town" tendencies.

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[1] For a further discussion of boomtown problems, see Gilmore, John S. "Boom Towns May Hinder Energy Development." Science, Vol. 191 (February 13, 1976), pp. 535-540; Kneese, Allan V. "Mitigating the Undesirable Aspects of Boom Town Development," pp. 74-76; Talagan, D.P., and W.E. Rapp. "Mitigation of Social Impacts on Individuals, Families, and Communities in Rapid Growth Areas," pp. 71-74 in Federation of Rocky Mountain States. Energy Development in the Rocky Mountain Region: Goals and Concerns. Denver, Colo.: Federation of Rocky Mountain States, 1975.

6.4.M Political and Governmental Impacts

Population growth and economic development at Kaiparowits/Escalante almost of necessity will increase the role of government in terms of demands for public services and facilities. As shown in the preceding analysis, most of these demands will fall on Kane and Garfield Counties, their localities, and to a lesser degree on Page, Arizona. The state government of Utah likewise will be affected, particularly with regard to legislative policies and programs, tax collection and distribution procedures, and other energy-related problems of statewide planning and growth management.

Immediate governmental impacts will occur as local communities, confronted with or anticipating rapid population increases, demand expenditures to provide essential services. In the case of Kane and Garfield Counties, the bulk of the population is located in the western half of each county. Most of the population increases, on the other hand, will take place in the resource areas, which are in the eastern parts of the area.

Although as noted in the fiscal analysis, revenues in the two Utah counties will be adequate to provide service improvements, problems may occur relative to the timing and distribution of available tax monies for communities if higher levels of government do not subsidize them. For example, even though Escalante's new revenues appear to keep pace with operating expenditures until the mid-1980's, later deficits expand to $530,000 per year. Furthermore, Escalante must build new facilities at a rate of $3.62 million per year during 1981-1985 if present tax rates are maintained in this community.

The timing problem (i.e., the potential impact of lagging revenues) for localities might be averted if resource developers choose to prepay all or a portion of the taxes anticipated from the facility development and if such monies are distributed to the point of impact. However, as enacted in 1975, the Utah sales and use tax prepayment provision is restricted in several ways.[1] First, it is voluntary on the part of the developer and appears to give no incentive to the developer to prepay (e.g., in the form of discounts, interest on tax credits, etc.). Second and more critical to mitigating local impacts are restrictions limiting aid to "state-related public improvements", such as schools and highways. The preceding fiscal analysis shows that the agencies primarily concerned with these projects (e.g., school districts) will manage without such assistance. The problem for state programs is not one of time, for these jurisdictions have surpluses from the start; rather, the problem is that municipalities need help in meeting their front-end financing problems.

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[1] Utah Code Annotated, §§ 63-51-1 *et seq.* (Cumulative Supplement 1975).

In addition to the above limitations, the process of distributing revenues collected through Utah's prepayment statute does not insure that the available funds will get to the point of need in a reliable manner. The Utah legislature is required to approve appropriations for public service projects to be funded, thereby increasing the length of time required for the disbursement of monies and raising the level of uncertainty as to their availability. This is especially significant because the legislature meets only once every 2 years.

There also appears to be some question as to the adequacy of the increased revenues which Page and Coconino County can expect to receive for purposes of service and facilities improvements. In Page, Arizona, operating deficits widen continually during 1980-1990. Some fiscal adjustments may be required by the respective local and county governments because Arizona must depend on ad valorem property taxes and assessed valuations connected with population growth and increased sales taxes to finance public improvements.

Fiscal impacts and problems of tax distribution underscore the importance of adequate planning at every level of government. The planning capacity of Kane and Garfield Counties, as previously indicated, is limited. Only Kane County has a zoning ordinance and planning commission, and both staffs are small. The Kaiparowits Planning and Development Council was established to provide the two Utah counties access to additional professional planning expertise. In addition, the state has taken several earlier steps to reinforce the role and capabilities of local officials by developing a planning and coordination structure to assist localities.[1] Beginning in May 1970, eight multicounty planning districts (since reduced to seven) were established by executive order of the Governor. Members of the designated districts formed associations of government (AOG's), with Kane and Garfield joining the Five County AOG in southern Utah. Generally, membership in the Five County AOG is composed of elected city and county officials; however, it includes elected members of the school board and invited representatives of higher education and state legislators to sit ex-officio. The association decides what issues it chooses to deal with, what funds it accepts for these purposes, and whether it will undertake direct operation of programs. The AOG also sends representatives to the Governor's Advisory Council on Local Affairs (GACLA) to coordinate local involvement in the state government planning process.

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[1] Information on the Utah intergovernmental planning structure is summarized mainly from Utah, State Planning Coordinator and Department of Community Affairs. Intergovernmental Planning Coordination: The Utah Experience. Salt Lake City, Utah: State of Utah, 1975.

Besides the GACLA, the governor of Utah has another statewide advisory group, the State Planning Advisory Committee, which seeks to coordinate the responses of state agencies to both federal and local issues and bring state agencies under a common set of priorities and policies.[1] This committee and the multicounty AOG serve additionally as state and area clearinghouses under the federal Office of Management and Budget A-95 review procedures.[2]

As described above, Utah's arrangements and procedures for intergovernmental coordination remain largely untested, at least in terms of the energy-related problems the state confronts in this scenario. Until the scenario unfolds over time, it will remain unknown whether the typical lag between the need for government planning and services and their provision will or will not prevail here. The fact that there is so much federal land in the area suggests that proper planning in advance will be even more essential in this scenario than elsewhere.[3] It also suggests that the market for the best land could easily be bid out of reach of all but large, nonlocal interests. Further, the location and status of the Kaiparowits new town will raise numerous issues involving both the state and county governments, as well as federal-state relations.

Besides facility finances, another traditional category of government concern that may be affected by energy resource development is police protection; that is, increases in area crime due to energy-related development and population increase might result in law enforcement problems.[1] However, increases in crime appear to vary greatly from community to community and are not always perceived to be disproportionate.[2] Present law enforcement personnel will be insufficient for the communities likely to be affected, and salary disparities between area law enforcement and energy facility security jobs may result in loss of some community officers to the higher paid positions.

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[1] To carry out its duties, the State Planning Advisory Committee has established three interdepartmental coordination groups within three major categories: Human Services, Economic and Physical Development, and Regulatory.

[2] Office of Management and Budget Circular A-95 establishes the requirement for states to provide the opportunity for governors and local officials to comment on applications for federal funds to undertake a variety of categorical programs, and requires agencies of the federal government to consider the comments of the general public in approving specific applications for funds. Numerous federal grants for facilities and services require A-95 review procedures as a condition for their award.

[3] For example, police and fire protection and medical care involve important locational and accessibility criteria that must be considered. The unavailability of federal land could constrain such services to very non-optimal sites if the best sites are either on federal land or are sold for other uses.

In addition to impacts noted above, energy development at Kaiparowits/Escalante may result in changes for traditional organized interests and could, over the long run, affect the power base of political groups and other parties-at-interest in energy-impacted communities. For example, the change in land use from ranching and tourism to urban, industrial, and residential activities will result in social and political stress in the area. Long-time residents whose way of life, and possibly livelihood, are threatened by energy development could become a political force that might make additional demands on the developers. Although the southern Utah mood is generally pro-development, some groups will be affected more severely than others and in some ways anticipated by them. Therefore, some political differences appear likely. These may well be exacerbated if, as is likely, newcomers displace natives on the governing bodies of city and county governments and in such organizations as PTA's, Chambers of Commerce, etc. If construction-related residents, who are known to be temporary, are perceived to be overly active politically, hostility can result.

6.4.9 Summary of Social, Economic, and Political Impacts

The Kaiparowits/Escalante development will result in an approximate 400-percent population increase for southern Utah (to more than 25 thousand people) by 1990. The largest local increases should occur in Escalante and at the Kaiparowits new town. However, much of the secondary employment personnel will be attracted to Page, Arizona. Housing and school needs will be greatest at Escalante, less at the new town (where the development plan should anticipate demand with several school buildings).

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[1] Crime rates have often increased in other boom towns. See Coon, Randal C., et al. The Impact of the Safeguard Antiballistic Missile System Construction on Northeastern North Dakota. Agricultural Economics Report No. 101. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1976, pp. 15-16; Gilmore, John S. "Boom Towns May Hinder Energy Development." Science, Vol. 191 (February 13, 1976), pp. 535-540.

[2] Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976.

and less at Page, where the increase will be fairly gradual and will balance with the downturn in activity from construction of the Navajo power plant.

A long-term impact on the age structure in the area will result, with younger workers and families moving into an area which has recently seen much out-migration by young adults. In the short term, an imbalance of males and females could cause social problems during project construction. The average income in the area will increase by at least 24 percent, and, except for Coconino County and Page, governmental revenues will increase. Most all of the impacts will occur in the eastern portions of the two counties, the area now least populated. This will intensify the planning for and delivery of social services, and it may result in some tension between the new population in the east and the natives in the west.

Revenues generated by the development will support the expansion of public services and professional staff required in southern Utah. However, Page will not benefit directly and will suffer a net loss in providing services to the portion of the population increase expected to locate there.

By 1990, most of the negative economic impacts associated with population increases will have been absorbed. From this time forward, economic impacts will be almost entirely beneficial, especially in terms of tax revenues and personal income.

6.5 ECOLOGICAL IMPACTS

6.5.1 Introduction

The area considered for ecological impacts in the Kaiparowits/Escalante scenario extends northward from the Colorado River to include the Aquarius Plateau and Boulder Mountain. The western boundary is the Paria River and the eastern boundary is the Henry Mountains. Topographically, the area is a series of benches or plateaus, separated by steep cliffs as much as 2,000 feet in height. The entire landscape rises gradually from 4,000 feet in the semiarid benchlands at Glen Canyon Dam to more than 10,500 feet on the relatively moist Aquarius Plateau. Elevational change, with associated rainfall variation of 6-20 inches per year, is the major factor determining the distribution of predominant plant communities. Within each community type, soil moisture largely determines the relative abundance of plant species.

6.5.2 Existing Biological Conditions

Biological communities in the Kaiparowits Plateau area are comprised primarily of plants and animals adapted for survival in a harsh, arid or semiarid environment.[1] Nevertheless, these populations fluctuate from year to year in response to climatic variations, especially in the amount of moisture. Slight variations in precipitation can cause major changes in the production of plants; in turn, the levels of plant productivity tend to place a ceiling on the potential abundance of animal life.

The flora of the Kaiparowits Plateau contains a blend of cold and warm desert species, resulting in a diversity of plant life. The dominant vegetation types in the immediate vicinity of the hypothetical energy facilities are pinyon-juniper woodland on the plateau and several desert shrub and grassland communities at lower elevations toward the Colorado River.[2] Some soilless, rocky areas are entirely barren. At the Kaiparowits facility site, pinyon pine and juniper trees cover up to 62 percent of the surface. Mountains to the north support coniferous forests that consist mostly of ponderosa pine and Douglas fir.

Animal life is diverse but sparse, probably because accessible water is relatively scarce. Large mammals include mule deer, pronghorn antelope, mountain lion, coyotes, foxes, and bobcats.[3] Over 200 species of birds use the area at least seasonally, and about 60 species of smaller terrestrial vertebrates occur, including mammals, reptiles, and amphibians.[4] The only rare or endangered species known to occur in the area directly affected by the scenario activities is the peregrine falcon, which occasionally appears in the summer.[5] Table 6-34 summarizes characteristic species of the major terrestrial community types in the scenario area.

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[1] U.S., Department of the Interior, Southwest Energy Federal Task Force. Southwest Energy Study, Appendix H: Report of the Biota Work Group. Springfield, Va.: National Technical Information Service, 1972. PB-232 104, pp. 23-30.

[2] Ibid.

[3] Bighorn sheep occur in the Circle Cliffs area, which is the northern border of the Escalante River Valley.

[4] Some of the small mammals may be important to arid southwest ecosystems. For example, kangaroo rats help maintain nutrient cycles. Chew, R.M., and A.E. Chew. "Energy Relationships of the Mammals of a Desert Shrub (Larrea tridentata) Community," Ecological Monographs, Vol. 40 (1970), pp. 1-21.

[5] A colony of the endangered Utah prairie dog is located about 75 miles to the north, and another has been introduced in Bryce Canyon to the west.

TABLE 6-34: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, KAIPAROWITS/ESCALANTE SCENARIO

Community Type	Characteristic Plants	Characteristic Animals
Salt Desert Shrub and Grasslands	Blackbrush Spiny hopsage Shadscale Rabbitbrush Galleta grass Indian ricegrass	Pronghorn antelope Buffalo Canyon mouse Chukar Horned lark Side-blotched lizard Coyote Badger
Rugged Areas	Same as desert shrub	Bighorn sheep Rock squirrel Bats Birds of prey Mountain lion Bobcat
Pinyon-Juniper Woodland	Utah juniper Double-leaf pinyon Buffaloberry Cliffrose Sagebrush Indian ricegrass Blue grama	Mule deer Desert cottontail Bushytail woodrat Pinyon jay Chickadee Coyote Fox Mountain lion Bobcat
Plateau Coniferous Forest	Ponderosa pine Douglas fir Engelmann spruce Aspen Gambel oak	Mule deer Black bear Wild turkey Band-tailed pigeon Beaver Chipmunk species Clark's nutcracker Dipper Coyote Bobcat

The physical and chemical properties of Lake Powell make it a productive lake with a largely self-sustaining sport fishery. The lake supports about 19 species of fish via a food chain that includes a diversity of algae and invertebrates. The lake is primarily a warm water habitat, and fishes such as largemouth bass are abundant in the upper water layers and shallow bays. Deeper, cooler layers contain trout.

6.5.3 Major Factors Producing Impacts

During the 1975-1980 period, construction of the Kaiparowits power plant will begin, with the labor force peaking in 1980. Population increases during this period center in a new town to be built on East Clark Bench, which is expected to have a population of 2000 by 1980. Population in Kane County as a whole increases by 70 percent during this 5-year period. Construction of the new town will remove a total of 3,900 acres of salt-tolerant shrub grassland, while the new Cannonville-Kaiparowits highway and the Kaiparowits plant facilities completed by 1980 will claim a total of 8,210 acres,[1] approximately equally divided between pinyon-juniper woodland and shrub grassland. Table 6-35 summarizes these vegetation losses.

Between 1980 and 1990, the Kaiparowits plant will come on line (1983), followed by the Escalante plant (1987). Transmission lines for both plants will be built during this decade.

TABLE 6-35: VEGETATION LOSSES: KAIPAROWITS/ESCALANTE SCENARIO (acres)

Community Type	1975-1980	1980-1990	1990-2000	Cumulative Total
Pinyon-Juniper	4,110	5,130	40	9,280
Salt-tolerant shrub grassland	4,080	1,070		5,150
Plateau conifers		350		350
Ponderosa pine			290	290
Sagebrush			50	50
Barren land	20	140		160
Total	8,210	6,690	380	15,280

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[1] Includes only that portion of the mine site to be occupied by surface structures.

Habitat lost in the 1980-1990 decade is principally pinyon-juniper woodland with smaller amounts of shrub-grassland, plateau conifers, and barren land as shown in Table 6-35. Also during this decade, the population of Kane and Garfield counties will rise by an additional 54 percent and 216 percent, respectively; the Kaiparowits new town will have about 6,940 residents in 1990. Page, Arizona will act as a secondary focus of growth and will have grown by a cumulative 15 percent by 1990. The town of Escalante will grow from 900 to 9,730 persons in this period.

Between 1990 and 2000, the only major impacts on habitat availability will arise from working the limestone quarry which will serve both plants. Cumulatively, the quarry will occupy 380 acres, mostly in ponderosa pine. Population will continue to climb slightly, growing by 5 percent in both Kane and Garfield counties. Page's population will rise by roughly 6 percent.

Figure 6-11 shows the distribution of energy facilities and the associated human activities likely to have the greatest impact on ecosystems. Some of these land-use trends are now evident or could occur regardless of energy-related growth. However, their extent is directly related to the number of people drawn into the area by the energy resource developments.

6.5.4 Impacts

A. Impacts to 1980

During most of this period, construction activity will be limited to clearing the Kaiparowits plant site, building heavy-duty access roads, and laying the plant water line. Construction activities will peak at Kaiparowits by 1980, the year when activities at Escalante will be just beginning.

Impacts on agriculture during this period will be confined to the loss of grazing on lands used for scenario facilities. Carrying capacity for livestock has been assumed to be 10-15 acres of forage per month for a cow and calf[1] in pinyon-juniper rangeland and 18-22 acres of forage per month for a cow and calf in salt-tolerant shrub-grassland. Land commitments for the scenario would therefore eliminate the forage normally used in a year by 60-90 cows and calves. Normally, these lands are used for only 6 months in the winter or summer. Therefore, the maximum number of cows with calves represented by this loss is 120-180. Further, not all lands affected by the scenario are grazed under the present Bureau of Land Management (BLM) program. Consequently, potential livestock reductions are less than this maximum.

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[1] The forage required to support a cow with calf or five sheep for a month is called an animal unit month.

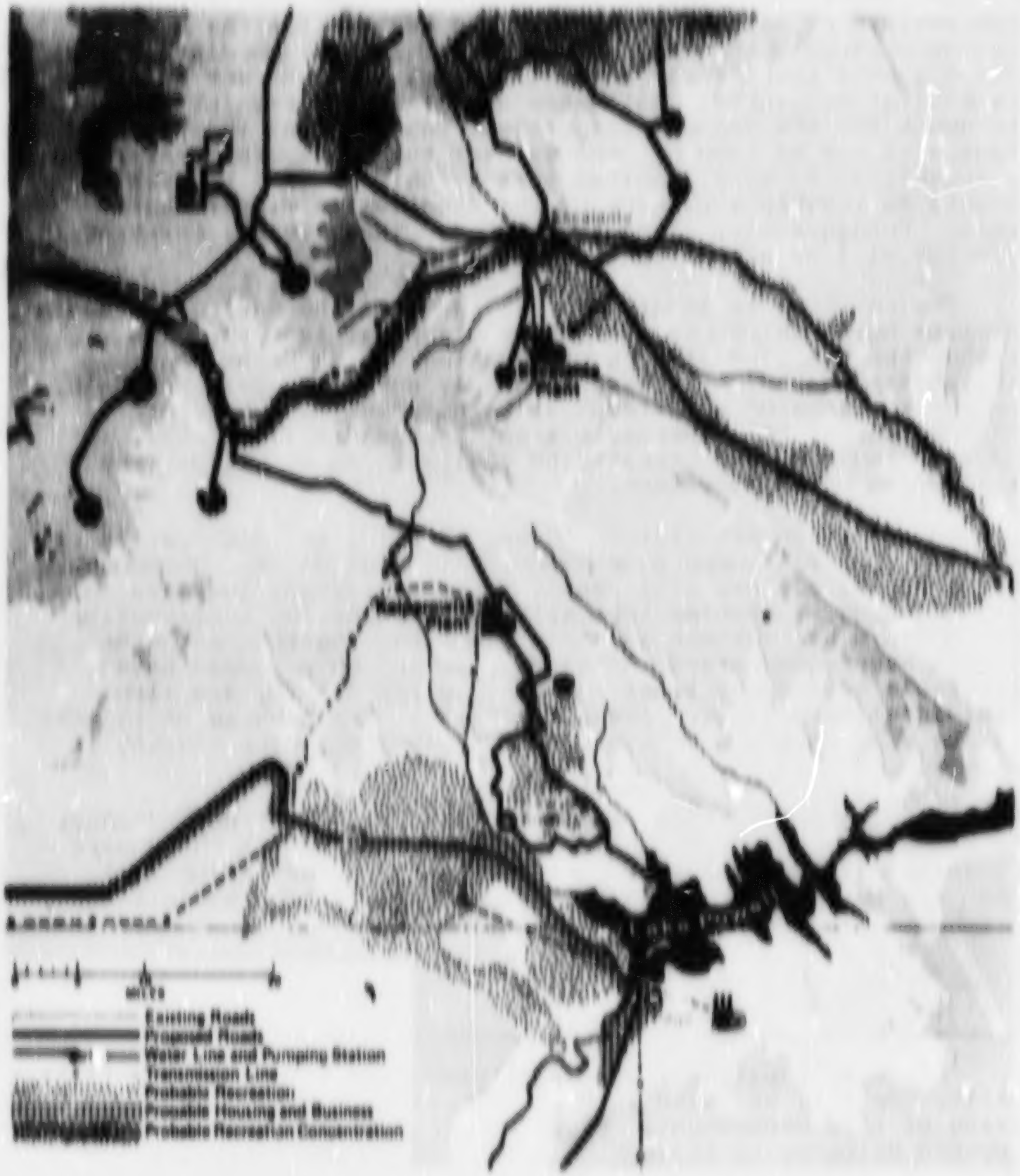
MILES
Existing Roads
Proposed Roads
Water Line and Pumping Station
Transmission Line
Probable Recreation
Probable Housing and Business
Probable Recreation Concentration

FIGURE 6-11: HUMAN ACTIVITIES IN THE KAIPAROWITS/ESCALANTE AREA

Most of the habitat lost in this period will be in pinyon-juniper woodlands of the plateau. This habitat supports a wide variety of vertebrate species and constitutes the bulk of the winter range of the Kaiparowits deer herd. Deer are distributed unevenly over the plateau in small groups which do not fully use the habitat available. Estimates used in the Draft Environmental Statement for the Kaiparowits project suggest that the proposed plant site may be used by some 60 deer seasonally, or year-round by roughly 20.[1] Total habitat loss in this decade, however, amounts to roughly 1 percent of the Kaiparowits winter deer range. Consequently, it is not expected that overall carrying capacity will be significantly reduced.

The new town is located in the range of the East Clark Bench antelope herd, which may ultimately disappear from the area through the combined effects of poaching, harrassment, and habitat deterioration. These antelope, numbering perhaps 25-30, are the remnants of an attempt at reintroduction. Habitat quality, rather than available area, appears to limit their numbers, and they are expected to decline with or without the development of the new town.

Construction activities, noise, traffic, and high levels of human activity will cause some local stress to wildlife. Increased access to the plateau will result in a significant increase in game poaching, a problem typically observed during construction periods in other western areas.[2] Poaching, together with the present steady downtrend in the Kaiparowits herd, could have measurable effects on total numbers. Birds of prey are also traditional targets for illegal shooting. The problem of illegal killing will worsen when the Cannonville-Kaiparowits highway is built.

During the 1975-1980 period, increased recreational demands may be expected to exert their greatest influence on the desert ecosystem below the plateau rim. Extensive areas of BLM land, which are potentially attractive sites for off-road vehicle (ORV) use, lie within easy access of Page and the new town. Heavy use of these areas may eventually result in extensive local erosion and accompanying vegetation loss.[1]

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[1] Arizona, Department of Health Services, Bureau of Air Quality Control, as cited in U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[2] Unlike legitimate single-sex hunting, which is also likely to increase, poaching takes animals of both sexes and can affect the population's ability to maintain its numbers by reproduction.

B. Impacts to 1990

By the end of the second scenario decade, the Kaiparowits and Escalante plants will both be on-line, and population will have risen sharply. Also during this time frame, the limestone quarry to supply the power plant/scrubbers will be opened.

Removal of water from Lake Powell for the Kaiparowits project has been predicted to result in salinity increases of roughly 2 mg/l at Imperial Dam.[2] The present scenario would no more than double this effect, which would constitute approximately 0.3 percent of the salinity projected for the year 2000 by several agencies.[3] Thus, the impact of the scenario alone on downstream water use for irrigated agriculture will be negligible. Other agricultural impacts of the 1980-1990 decade stem from the loss of grazing land. Excluding transmission line rights-of-way, which may be reseeded and recover their grazing value, the forage lost is equivalent to the yearly forage requirements of 40-50 cows with calves. Not all the land disturbed is normally allotted to grazing; therefore, these numbers are a maximum. Based on 6-month pasturing, this amount of forage might support 80-100 cows with calves.

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[1] The seriousness of the impact of off-road vehicle use will depend on the success of efforts to control it on public lands; the kinds of trails made, and their manner of use. Where a trail is used infrequently and plant roots are not damaged, the vegetation may recover in one season. However, roads which climb slopes at steep angles and break the surface of the soil may begin to gully after about 5 years from infrequent but intense thunderstorms. (Personal communication with staff, Paria Unit, Bureau of Land Management, 1976).

[2] U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[3] Some published estimates of future salinity levels at Imperial Dam, range from 1220 mg/l, United States Bureau of Reclamation, to 1340 mg/l, Colorado River Basin Salinity Control Act of 1974, Pub. L. No. 93-320, 88 Stat. 266 (codified at 43 U.S.C.A. 1571 *et seq.*) (Supp. 1976). Note that if water for energy development were instead used for agriculture, runoff from croplands would result in larger increases in downstream salinity.

Habitat loss during this period is centered on the pinyon-juniper woodland of the Kaiparowits Plateau around Escalante, bringing the cumulative total loss to roughly 2 percent of the Kaiparowits deer range. A total of 1,220 acres of the pinyon-juniper habitat lost in this decade will be claimed by transmission line rights-of-way. While vegetation will be completely cleared, regrowth in the absence of root competition from trees may be equal or superior to the original vegetation as wildlife forage, especially if the right-of-way is seeded. This additional productive vegetational discontinuity may result in local increases in small vertebrate diversity. The limestone quarry lies adjacent to the range of a healthy antelope herd, but the bulk of the habitat to be disturbed is unsuitable for them.

Habitat quality will also be affected between 1980 and 1990 by several new influences. Increased traffic on new roads crossing the Kaiparowits Plateau will add to the yearly road-kill of animals, especially since the proposed Cannonville-Glen Canyon City highway right-of-way transects the present direction of deer migration.[1] Enhanced access to the plateau will probably increase the amount of game poaching and extend it to a wider area. The cumulative effects could result in continued decline in deer numbers.

Mining and groundwater withdrawal for municipal use will probably bring about a decrease in discharge to springs and seeps over an unspecified portion of the area. These discharges have a strong influence on the distribution of many kinds of wildlife, such as deer, mourning doves, and numerous small birds and mammals with restricted ranges that require accessible water to sustain life. The cumulative effect on the plateau ecosystem of groundwater losses, depending on the extent to which accessible water sources are affected, will be a combination of redistribution of water-dependent species away from depleted springs or seeps and perhaps a decrease in their overall population.

The loss of water from these sources will be partially mitigated by the addition of surge ponds on the water lines and on-site raw water reservoirs. Reservoirs located in the pinyon-juniper zone might be used by a variety of wildlife, provided that deer-proof fencing is not used. However, these reservoirs will not replace natural springs and seeps that support vegetation. Surge ponds will be located in the desert ecosystem where they will constitute a distinct benefit if not restrictively fenced. Partridge, pheasant, and quail could establish new populations around these ponds, provided other habitat requirements are met.

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[1] The Kaiparowits herd is already declining.

Treated municipal wastes may be discharged into the Escalante River from the town of Escalante. These wastes usually contain large amounts of nutrients that can stimulate algal growth. The amount of discharge would be insufficient to maintain base flow in the dry summer period. Nuisance algal blooms, causing odors and reducing dissolved oxygen, could result if the effluent stagnates in pools. Adverse impacts of this kind would be greatest at periods of low flow.

After the two power plants begin operations, air pollutants of various kinds will enter the atmosphere. Ground-level concentrations of sulfur dioxide are estimated to reach peak 3-hour average values of about 800 micrograms per cubic meter where plume impaction on high terrain may occur (see Section 6.2). This concentration is equivalent to about 0.3 parts per million (ppm), which is below acute damage levels for those desert plants which have been tested (acute damage has been measured in desert plants typically in the range of 3-10 ppm for 2-8 hour exposures). More sensitive desert species may exist but they have not [illegible]en tested. The potential for chronic damage may exist, but [illegible]'e are insufficient data to support a conclusion. Generally, [illegible]ge due to acid rainfall is not expected due to the low humidity and limited precipitation, although periods of active plant growth and hence increased susceptibility to acid rain are closely related to rainfall.

C. Impacts to 2000

By 1990, the population of Garfield County and Kane County (see Section 4.5) should triple. Thus, living space, water, and recreation needs in these counties will lead to both local and areawide changes in land use. ORV use, camping, hiking, and other activities will continue to affect vegetation locally and contribute to erosion. New roads to be developed by the Forest Service to accommodate increased recreational use will provide access to previously isolated areas.

Urban growth around Escalante, Page, and the Kaiparowits new town will result in an increase in ORV recreation on the deserts near Lake Powell. A new road planned to parallel Lake Powell's north shore will open access to new areas. In addition, poaching will continue along roads and near towns, although levels may decline somewhat after the Escalante construction peak. Residential growth will also result in fragmentation of habitat, particularly along highways following river valleys. If allowed to run free, dogs may also affect wildlife in the area.[1] The cumulative effect of these influences will be to reduce the abundance and diversity of wildlife within as much as 5-10 miles of residential centers.

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[1] Dogs have become a serious concern in some parts of Colorado; a review of the problem, from the sportsman's viewpoint, is given in Oertle, V. Lee. "What's Happening to Western States' Deer Hunting?" *Sports Afield* (September 1975).

Increased populations will add to the recreational pressure placed on the Dixie National Forest and nearby highlands. Major potential impacts include loss of vegetation cover, particularly around lake shores and stream banks as a consequence of uncontrolled camping and ORV use associated with fishing. Some summer deer range could also be affected. Loss of shore vegetation, if not controlled by restricting use of these areas, can lead to erosion and siltation problems which could lower the production of fish in lakes already under stress from a long-term drying trend. Continuing growth in fishing pressure will, by this decade, have depleted naturally reproducing trout populations, and the fishery will probably be maintained exclusively by stocking. Small parcels of privately owned land within the National Forest are expected to be developed as recreational subdivisions. This change in use will disturb wildlife and tend to fragment winter deer range. Hunting will also increase but can be controlled by employing management practices such as setting hunting seasons, limiting the numbers of permits issued, and setting bag limits. However, demand will probably exceed the amount of deer, and perhaps upland game birds, which can be harvested without a population decline.

Some of the long-term changes due to the outputs of facilities are potentially significant. For example, large wastewater impoundments may attract wildlife during dry periods, but it is not likely that animals will prefer the highly polluted water to the clean water in the plant raw water reservoirs.[1] Also, materials leached from these ponds may enter groundwater. Although recent evidence suggests that trace metals do not migrate far through soils, some salts (such as sulfates and carbonates) may.[2] The fate of the soluble organic compounds is uncertain. After the facilities are abandoned, the chemicals left in the evaporation ponds may eventually enter surface waters from dike failure or erosion. If high concentrations enter the shallow bays of Lake Powell, for example, fish might be killed or avoid the contaminated areas.

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[1] Crawford and Church found that captive black-tailed deer avoid salty (sodium chloride) and bitter (sodium acetate and acetic acid) solutions in concentrations well below those expected in an evaporation pond. Crawford, James C., and D.C. Church. "Response of Blacktailed Deer to Various Chemical Taste Stimuli." *Journal of Wildlife Management*, Vol. 35 (No. 2, 1971), pp. 210-15.

[2] Holland, W.F., *et al.* *The Environmental Effects of Trace Elements in the Pond Disposal of Ash and Flue Gas Desulfurization Sludge*. Final Report, Electric Power Research Institute Project No. 202. Austin, Tex.: Radian Corporation, 1975, p. 3.

Considerable concern has been expressed over the long-term contamination of Lake Powell by trace elements emitted in plant stack gases. For example, mercury can reach the lake from the facilities by direct fallout from emissions and by runoff. Calculations made for mercury deposition from the Kaiparowits plant alone range from 16 to 480 pounds of mercury entering the lake each year. These numbers are 1 to 27 percent of the present estimated rate of addition from natural sources. An unknown fraction of this input is converted to the organic form and enters the food chain. The emissions of the Escalante plant would contribute additional mercury, although the position of the site makes it likely that the amount would be less than that of Kaiparowits.

There is evidence to suggest that very small increases in mercury entering the aquatic food chain could result in elevations of mercury levels in fish tissues exceeding the limits set by the Food and Drug Administration (FDA) as safe for human consumption. Current levels in some predatory fish in Lake Powell exceed FDA standards of 500 ppm. Although based on limited knowledge, the movement of mercury as the elemental vapor from power plant emissions into the aquatic food chain has been estimated to cause increases of 10-50 percent in animal tissues, depending on number of plants, their location, and coal characteristics.[1] However, these estimates are based on limited data.

Arsenic additions from the facilities will deposit an estimated total of 600-5,000 pounds of arsenic per year. Unknown fractions of this would enter Lake Powell. The effects of this amount of arsenic on both terrestrial and aquatic portions of the food chain are largely unknown.

Additional toxic substances will be emitted from the power plants, including about 1,000 pounds of fluorides per year.[2] Manganese, chromium, nickel, and lead will be emitted in quantities comparable to the mercury releases. Expected ambient concentrations and effects of these materials on the ecosystem are largely unknown. Much larger quantities of the materials will either be removed from stack gases and deposited in the evaporative settling ponds or placed in ash disposal sites.

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[1] Standiford, D.R., L.D. Potter, and D.E. Kidd. *Mercury in the Lake Powell Ecosystem*, Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1973, p. 16.

[2] U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. III-65.

6.5.5 Summary of Ecological Impacts

Table 6-36 summarizes the impacts discussed in the preceding sections under three classes. Class C impacts are those which affect very small proportions (less than 3 percent) of the total available habitat of any given kind and/or occur infrequently, although the effect may be locally severe. Class B impacts are more widespread and have effects which may noticeably alter the composition of the entire ecosystem or may selectively affect a particular species. Class A impacts can potentially affect large proportions of a given habitat type or have severe impacts on populations of one or more species.

The cumulative impact of energy resource development on the ecosystem will most likely be to lower the diversity of wildlife locally, increase erosion, and contribute to the decline of several species. Specific populations of game animals and fish will experience selectively heavy stresses and decline in number. These impacts will result from the combined effects of direct habitat loss, habitat fragmentation, and diffuse human disturbances. Impacts on several major species are summarized in Table 6-37. Major contributors to these disturbances will include: habitat degradation in such areas as the high plateaus due to diffuse recreational activity; subdivision of lands for recreational developments; growth of residential and commercial land use and its influence on the quality of surrounding habitat; increased illegal hunting; and increased fishing in high plateau lakes.

Although these disturbances will not break down the structural and functional integrity of the ecosystems, local areas will probably experience internal adjustments affecting individual species populations. For example, development activities and anticipated increases in sport hunting for predators may minimize the importance of mountain lion as a natural predator of mule deer, but coyotes (and possibly wild dogs) will assume greater importance as predators.

Cumulative adverse influences are also expected to result in a long-term decline of the Kaiparowits deer herd and probably will hasten the loss of antelope from East Clark Bench.[1] Illegal

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[1] The influence of the scenario's impacts on habitat in the Dixie National Forest and on the benchlands just east of the Escalante River could render them less suitable or unsuitable for reintroduction of elk and antelope, now under consideration by the Utah Division of Wildlife Resources.

TABLE 6-36: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

Impact Category	1975-1980	1980-1990	1990-2000
Class A	Increased recreational use of high plateaus Illegal shooting	Increased recreational use of high plateaus Illegal shooting	Increased recreational use of high plateaus
Class B	Damage and harassment associated with ORV's in desert areas Habitat fragmentation, land use, road kill and harassment (urban influence)	Damage and harassment associated with ORV's in desert areas Urban influence Altered springs and seep discharge	Damage and harassment associated with ORV's in desert areas Urban influence Altered springs and seep discharge
Class C	Direct habitat removal Grazing losses	Direct habitat removal Grazing losses "Criteria" air pollutant emissions Local eutrophication of Escalante River by municipal sewage discharge	Direct habitat removal Grazing losses "Criteria" air pollutant emissions
Unknown		Addition of mercury and other trace elements to Lake Powell	Addition of trace elements to Lake Powell

ORV = off-road vehicle

TABLE 6-37: FORECAST OF STATUS OF SELECTED SPECIES[a]

	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[a] [illegible]

shooting could, over the long-term, cause declines in populations of the larger birds of prey. Aquatic ecosystems in the Dixie National Forest may also be locally degraded unless access is controlled; this stress, coupled with heavy fishing pressure, will have a severe impact on resident reproducing trout populations.

With the introduction of the energy facilities and projected population increase of approximately 20,000 people, some long-term alterations of vegetation may occur on a local scale. Although many of the immediate and direct impacts of construction activity and facility siting will probably have only short-term effects, other impacts may have more lasting effects. Some plant communities will be disrupted by immediate stresses and will undergo plant replacement or succession. Succession is not well understood in desert plant communities, perhaps because of the very long time required for change.[1] A series of successional plant community stages will probably occur on those sites directly disrupted by energy development and damaged by ORV use and subsequent erosion, and their return to a final or climax stage of development may take many years.[2]

One potential long-term effect from energy development on future ecolo[illegible]al systems may come from eventual accumulation of toxic elemen[illegible]itted from the power plants and entering the aquatic food [illegible]n in Lake Powell. However, incomplete understanding of the dynamics of the movements of mercury into and through the ecosystem make it difficult to predict the potential concentration in fish, although some studies indicate potentially significant increases. Also, the degradation of dikes enclosing the waste materials deposited in evaporation ponds may allow release of toxic compounds which will eventually enter the biological components of the ecological system.

Opening the area by providing easier access will be considered a benefit by some groups and a detriment by others. The wilderness character of the area will be largely lost; however, larger numbers of people will have access to the recreational and scenic benefits of the area.

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[1] On dune sands in Idaho, a situation somewhat analogous to a desert, Chadwick, H.W., and P.D. Dalke. "Plant Succession on Dune Sands in Fremont County, Idaho." Ecology, Vol. 46 (Autumn 1965), pp. 765-80, recognized five stages of succession: Stage 1 lasting about 30 years; Stage 2 lasting 20-70 years; Stage 3 lasting 50-70 years; and Stage 4 lasting 700-900 years before the final or climax stage becomes dominant.

[2] Whitfield, C.J., and H.L. Anderson. "Secondary Succession in the Desert Plains Grassland." Ecology, Vol. 19 (April 1938), pp. 171-80.

6.6 OVERALL SUMMARY OF IMPACTS AT KAIPAROWITS/ESCALANTE

A major benefit resulting from the hypothetical energy development called for in the Kaiparowits/Escalante scenario will be the production of 6,000 megawatts-electric of electricity. This benefit will accrue more to people outside than inside the areas. Locally, the principal benefits will be economic, including substantial increases in per-capita income, retail and wholesale trade, and secondary economic development. In addition, Kane and Garfield Counties will receive substantial new tax revenues, and the state of Utah will benefit noticeably. These benefits will support the expansion of public services and professional staffs presently needed in southern Utah. Some persons, both locals and tourists, will consider new roads in previously inaccessible areas to be a benefit.

Many of the major negative impacts that can be anticipated will result either directly or indirectly from the expected 300-percent population increase for southern Utah by 1990. Some local governments will be hard-pressed initially to provide the services required. Existing school, housing, health, and public safety services will be initially overwhelmed by the influx of workers and their families. Local governments in the area are generally not well-equipped to respond to the needs of this new population. However, planning capabilities are being upgraded, and the adequacy of existing controls, such as zoning, is now being assessed. These problems are surmountable, and the economic impacts of population increases will be predominately positive by 1990. With the exception of Page, long-term revenues produced by the development will be more than adequate to pay for the necessary services and the required additions to the professional staffs of local governments.[1] Since it will not share in the direct tax revenues produced by the energy facilities, Page will subsidize services to those workers and their families who choose to live there.

Newcomers will outnumber natives very early during the development. As indicated in the social and cultural impacts discussion above, the lifestyles of the natives and newcomers are likely to be quite different. While small in terms of numbers, at least some of the natives will consider the resultant political and social changes detrimental.

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[1] There might be problems due to a lag between the need to provide services and receipt of income to provide. However, this problem is lessened by Utah's law permitting local governments to require the prepayment of taxes.

Air quality impacts of energy development in the Kaiparowits/Escalante area will result from both the power plant and population increases. The Escalante plant may produce air impacts which will exceed significant deterioration standards for a Class II area. Visibility will also be adversely affected, especially during winter stagnation periods. Given the extensive recreational use of the area, particularly in the numerous nearby national parks and forests, this impact must be considered significant.

Power plant scrubbers are rated as 80-percent efficient in removing sulfur dioxide (SO_2). Scrubbers with 95-percent efficiency would result in no violation of Class II SO_2 standards. Elimination of scrubbers would result in significant violations of anticipated nondegradation air quality standards and would violate short-term (3-hour and 24-hour) primary and secondary air quality standards.

Water quality impacts will be minimized by the use of holding ponds. However, downstream users are likely to be affected by the increased total dissolved solids content of surface water resulting from the consumptive use of 84,000 acre-feet of surface water by the energy facilities. The new town and urban population require 12,000 acre-feet per year of groundwater. The total water resources of the Upper Colorado are already allocated, and the use of water for energy development will eventually mean that water will not be available for other uses. Water quality may also diminish from pond leakage, erosion, and inadequate sewage treatment facilities.

Potential water quality problems affecting aquatic life include excessive plankton growth from inadequately treated municipal sewage, stream flow reductions that restrict aquatic and riparian habitat, and additions of mercury from the power plants into the Lake Powell ecosystem. Current mercury concentrations in some predatory fish exceed the Food and Drug Administration standards, and additional mercury will contribute to this problem. Terrestrial animal populations are most likely to be affected from the combined disturbances of increased habitat fragmentation, legal and illegal hunting, and other recreational activities.

CHAPTER 7

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE NAVAJO/FARMINGTON AREA

7.1 INTRODUCTION

The hypothetical energy development proposed in the Navajo/Farmington scenario consists of coal mining, electrical power generation, Lurgi and Synthane high-Btu (British thermal unit) gasification, and Synthoil liquefaction.[1] The area within which development is to take place is shown in Figure 7-1; Figure 7-2 shows the location of specific facilities. Electricity generated in the area will be transported via extra-high voltage transmission lines to demand centers in Arizona, California, and New Mexico. The synthetic gas will be fed into existing pipeline networks in the Southwest, and the synthetic liquids will be pipelined to western and/or midwestern refineries. These facilities will be constructed between 1977 and 2000. The construction timetable and the technologies to be deployed are shown in Table 7-1.

In addition to this hypothetical energy development, the Navajo Indian Irrigation Project will become operational during the late 1970's. Because of its size, this development is also taken into account when impacts are analysed.

Two distinctive cultures are found in the Navajo/Farmington area: the Indian culture centered on the Navajo Reservation, and the predominantly non-Indian culture centered in Farmington. A similar division exists in the economy of the area.

San Juan County's non-Indian economy is diversified among several sectors of activity. Wholesale and retail trade, government, transportation and communications, mining, manufacturing,

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[1] While this hypothetical development may parallel development proposed by the Public Service Company of New Mexico, Utah International, Inc., Western Gasification Company, Consolidation Coal Company, El Paso Natural Gas Company and others, it must be stressed that the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

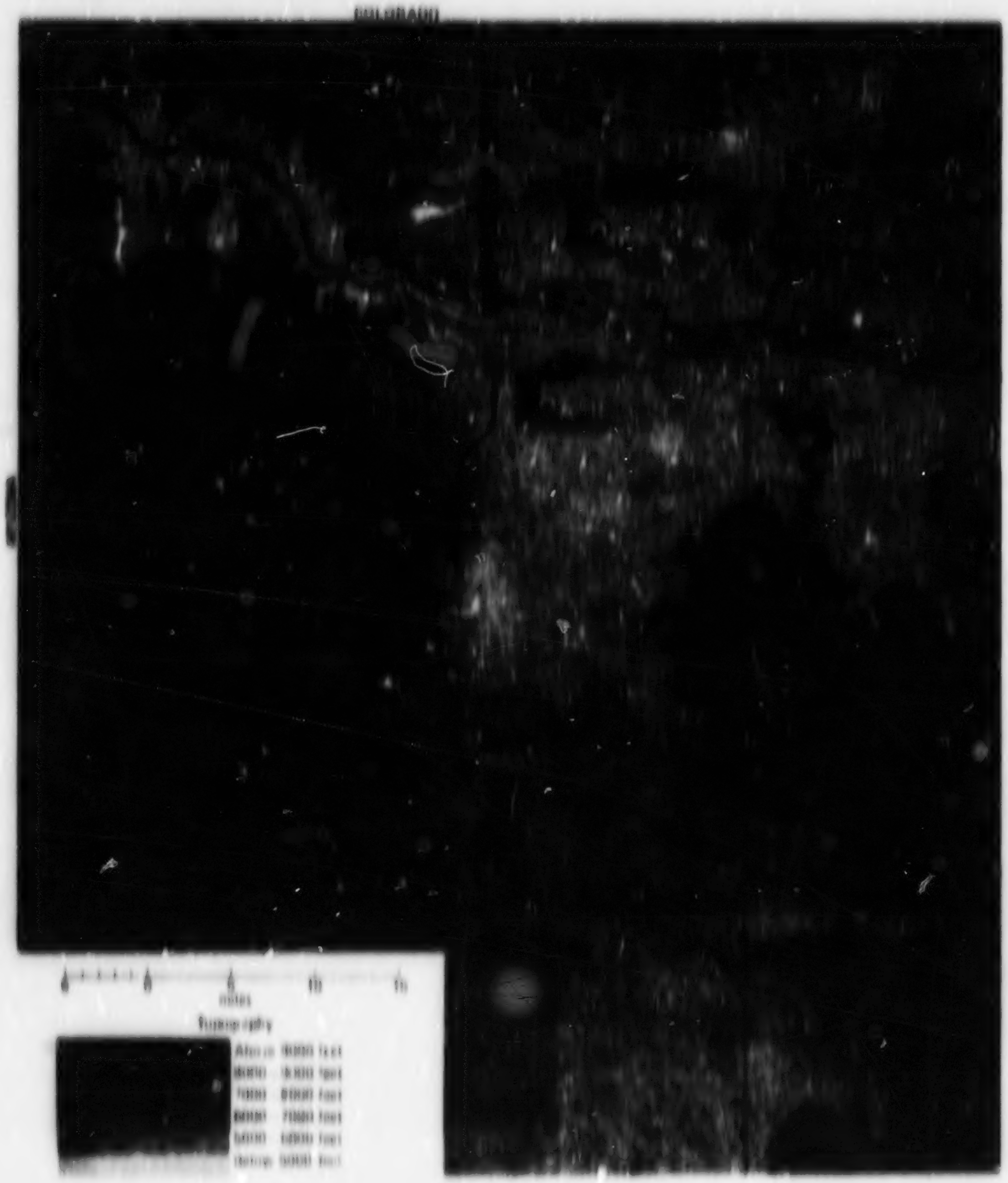

FIGURE 7-1; THE NAVAJO/FARMINGTON SCENARIO AREA

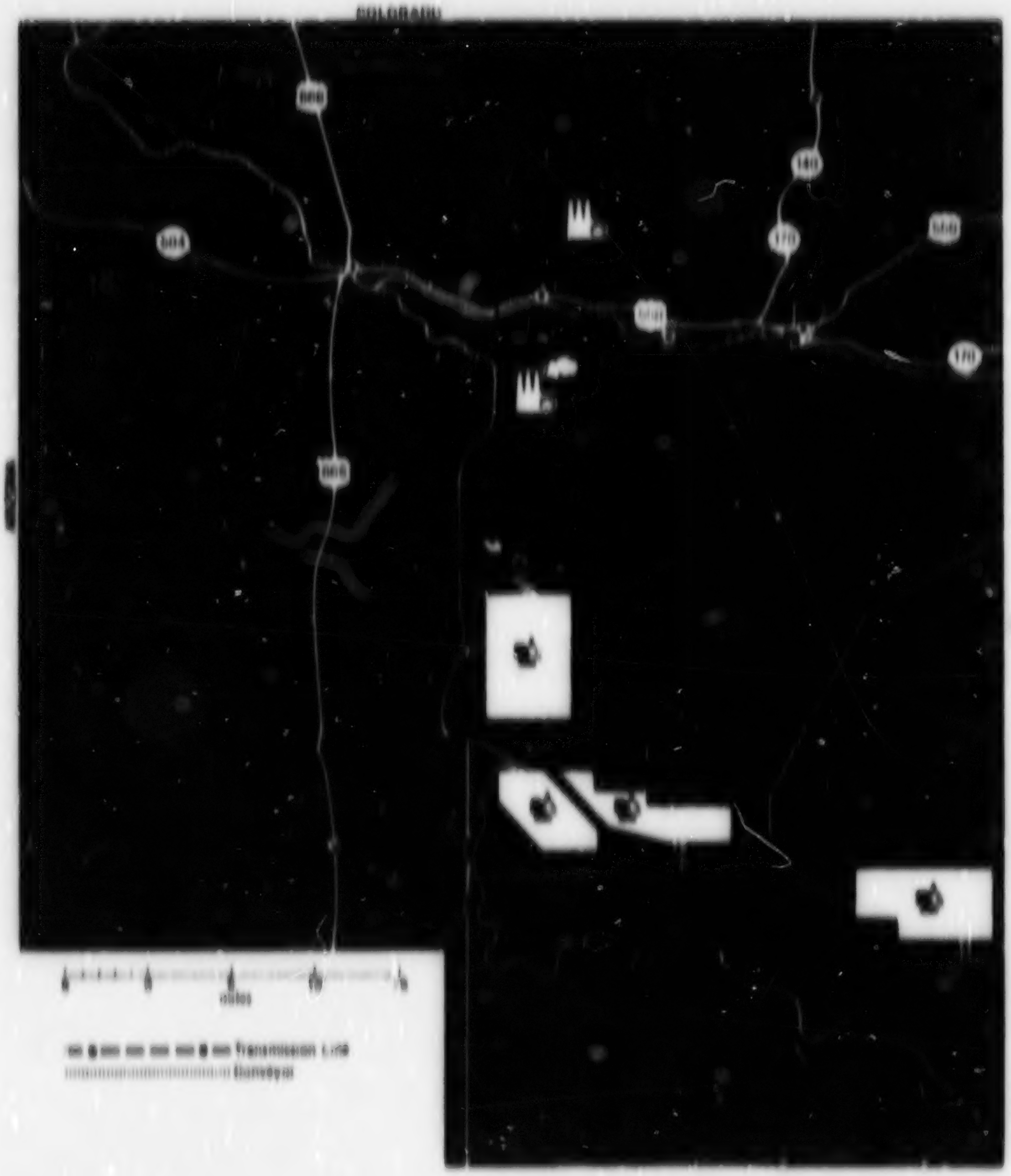

FIGURE 7-2: THE LOCATION OF ENERGY DEVELOPMENT FACILITIES IN THE NAVAJO/FARMINGTON AREA

TABLE 7-1: RESOURCES AND HYPOTHESIZED FACILITIES AT NAVAJO/FARMINGTON

Resources	Characteristics		
Coal[a] (billions of tons) Resources [illegible] Proved Reserves [illegible]	Coal Heat content 8,580 Btu's/lb Moisture 16 % Volatile Matter 33 % Fixed Carbon 34 % Ash 16 % Sulfur 0.7 %		
Technologies	**Facility Size**	**Completion Date**	**Facility Serviced**
Extraction Four surface area mines of varying capacity using draglines	7.3 MMtpy 12.2 MMtpy 6.6 MMtpy 13.3 MMtpy	1979 1984 1989 1999	Lurgi Plant Power Plant Synthane Synthoil
Conversion One Lurgi coal gasification plant operating at 72% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal, wet forced-draft cooling towers	250 MMscfd	1980	
One 3,000 MWe power plant consisting of four 750 MWe turbine generators; 34% plant efficiency; 80% efficient limestone scrubbers, 99% efficient electrostatic precipitator, and wet forced-draft cooling towers	1,500 MWe 1,500 MWe	1984 1985	
One Synthane coal gasification plant operating at 80% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal, wet forced-draft cooling towers	250 MMscfd	1990	
One Synthoil coal liquefaction plant operating at 67% thermal efficiency; Claus plant H_2S removal, wet forced-draft cooling towers	100,000 bbl/day	2000	
Transportation Coal Conveyor belts from mines to each facility			
Gas One 30-inch pipeline	250 MMcf	1980	Lurgi Plant
Oil One 16-inch pipeline	100,000 bbl/day	2000	Oil Well Field
Electricity Two EHV lines	765 kV	1984	Power Plant

bbl/day = barrels per day
Btu's/lb = British thermal units per pound
EHV = extra-high voltage
H_2S = hydrogen sulfide
kV = kilovolts

kWe = kilowatt-electric
MMcf = million cubic feet
MMscfd = million standard cubic feet per day
MMtpy = million tons per year
MWe = megawatt(s)-electric

[a] *1974 Keystone Coal Industry Manual*. New York, N.Y.: McGraw-Hill, 1974, p. 477; proved reserves are calculated as 50 percent of the defined resources. Values are for strippable coal from the Navajo field.

and agriculture are among the principal employers within the county. The Indian economy is predominantly agricultural.

The county is governed by a three-member board of commissioners and served by a professional manager. In 1975, a Planning and Research Department was established, primarily to assess needs arising from new developments within the county.

Services provided in the unincorporated sections of the county include police (a sheriff's department), fire (provided jointly with the state), and highway construction and maintenance. Public health care and public assistance are provided jointly by the county and state.

There are three incorporated urban areas in the county: Farmington, Aztec, and Bloomfield. Basic public services are provided in all three, and a separate school district serves each.

Although there are many unresolved questions concerning relationships between Indians and non-Indians, the applicability of state laws to Indians, the applicability of Indian laws to non-Indians, etc., the Navajos and Utes maintain a general sovereignty over their reservation lands. The Navajo Reservation, on which several energy facilities will be located, is governed by a Tribal Council.[1] Members of the Council are elected from Chapters into which the Reservation is divided.[2] A Chairman of the Tribal Council is elected at large.

Within the past few years, the Navajos have expanded the capabilities of the tribal government, largely in direct response to prospective energy development. For example, the Council is now served by a professional planning staff, and environmental and tax commissions have been established.

The reservation is predominantly rural. Shiprock, the only urban area in the New Mexico portion of the reservation, is unincorporated and governed by the Tribal Council.

The area to be developed is in the San Juan River Basin. The San Juan, the only perennial stream in the area, will be the source of water for the proposed energy facilities. Although there is groundwater in the area, it is limited in quantity and is generally of poor quality.

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[1] See Price, Monroe E. *Law and the American Indian*. Indianapolis, Ind.: Bobbs-Merrill, 1973; and Cohen, Felix S., ed. *Statutory Compilation of the Indian Law Survey*. Washington, D.C.: Government Printing Office, 1940.

[2] As established in 1923, the tribal government is basically a federal system in which the Chapters are the constituent units.

Rainfall averages only about 7 inches per year. This limits the amount and variety of vegetation, and the area contains mostly desert grasslands and shrubs. In some locations, overgrazing by Navajo-owned sheep has led to serious soil erosion and elimination of vegetation.

Air quality in the area is already affected by the San Juan and Four Corners power plants, refineries, and a variety of industrial facilities. Blowing dust also affects existing air quality. Selected descriptive characteristics of the area are summarized in Table 7-2. In each of the following sections, additional information is introduced as needed in the analysis of impacts.

TABLE 7-2: SELECTED CHARACTERISTICS OF THE NAVAJO/FARMINGTON AREA

Environment	
Elevation	6,000-9,000 feet
Precipitation	6-8 inches annually
Air Stability	Air stagnation during fall and winter
Vegetation	Sparse grasses and shrubs with barren areas, pinyon and juniper in foothills
Social and Economic (San Juan County)	
Land Ownership	
Indian	60 %
Federal	30 %
State	5 %
Private	5 %
Population Density	11.2 per square mile
Unemployment[a]	8.2 %
Income[b]	$3,147 per capita annual

[a] 1973 data.

[b] 1972 data.

7.2 AIR IMPACTS

7.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Navajo/Farmington area is currently affected by numerous emission sources, the largest of which are the Four Corners and San Juan Power Plants (Figure 7-1). Concentration measurements of criteria pollutants[1] taken in 1974 in the Four Corners area indicate that 24-hour average particulate levels exceed both federal and New Mexico standards due to blowing dust.[2] However, measurements taken at the site of the proposed Western Gasification Company gasification plant[3] do not indicate violations of either particulate or sulfur dioxide (SO_2) standards. Based on these measurements, annual average background levels have been estimated for three pollutants: SO_2,

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[1] Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, non-methane hydrocarbons (HC), nitrogen dioxides, oxidants, particulates, and sulfur dioxide. Although only non-methane HC are technically covered by the standards, the more inclusive term "hydrocarbons" is generally used. The HC standard serves as a guide for achieving oxidant standards.

[2] Utah Engineering Experiment Station. *Air Pollution Investigation in the Vicinity of the Four Corners and San Juan Power Plants*, Progress Report. Salt Lake City, Utah: March 1973, and amended by letter January 1974. As cited in U.S., Department of the Interior. *Draft Environmental Statement for Proposed Modification of Four Corners Power Plant and Navajo Mine*. Washington, D.C.: Government Printing Office, 1975.

[3] U.S., Department of the Interior, Bureau of Reclamation. *Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement*, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

20 $\mu g/m^3$ (micrograms per cubic meter); particulates, 40 $\mu g/m^3$; and nitrogen dioxide (NO_2), 10 $\mu g/m^3$.[1]

B. Meteorological Conditions

The worst dispersion conditions for the Navajo/Farmington area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), unchanging wind direction, and relatively low mixing depths.[2] These conditions are likely to increase concentrations of pollutants from both ground-level and elevated sources.[3] Since worst-case conditions differ at each site, predicted annual average pollutant levels vary among sites, even if the pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion more than 40 percent of the time. Hence, plume impaction and limited mixing of plumes caused by temperature inversions at plume height can be expected to occur regularly.[4] Good dispersion conditions are expected to occur about 20 percent of the time.[5]

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[1] These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are now assumed to be relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles. Estimates of longer range visibilities have been made. For example, the background visibility has been estimated at 70-100 miles, depending on the direction that is viewed. Visibility is reduced when looking across the Four Corners' Plume. See R. Nicholson, Progress Report, New Mexico Visibility Study. Santa Fe, N.M.: New Mexico Environmental Improvement Agency, n.d.

[2] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[3] Ground-level sources include towns and strip mines that emit pollutants close to ground level.

[4] See National Climatic Center. Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities. Ashville, N.C.: National Climatic Center, 1976.

[5] Jordan, R.A. Joint Ambient Air Monitoring Project, Interim Report. Albuquerque, N.M.: Public Service Company of New Mexico, September 1973, and amended January 1974. As cited in U.S., Department of the Interior. Draft Environmental Statement for Proposed Modification of Four Corners Power Plant and Navajo Mine. Washington, D.C.: Government Printing Office, 1975.

As at most western sites, the potential for dispersion of pollutants in the Navajo/Farmington area varies considerably by season. During spring and summer, strong low-level winds (15-25 miles per hour enhance dispersion potential. During winter months, dispersion potential is often limited because of persistent high pressure areas near the surface over the Colorado River Plateau.

7.2.2 Emissions Sources

The primary emissions sources in the Navajo/Farmington scenario are a power plant, three conversion facilities (Lurgi, Synthane, and Synthoil), supporting surface mines, and population increases. Pollution from energy-related population was estimated from available data on average emissions per person in several western cities.[1] Most mine-related pollution originates from diesel engine combustion products, primarily nitrogen oxides (NO_x), hydrocarbons (HC), and particulates. Although dust suppression techniques are hypothesized in the scenario, some additional particulates will come from blasting, coal piles, and blowing dust.[2]

The hypothetical power plant in this scenario has four 750 megawatts-electric (MWe) boilers, each with its own stack.[3] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2 and 40 percent of the NO_x.[4] Two 75,000-barrel storage tanks at the plant, with standard floating roof construction, will each emit up to 0.7 pound of HC per hour.

The power plant and the three coal conversion facilities are cooled by wet forced-draft cooling towers. Each cell in the tower circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,200 pounds per year for each cell.[1]

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[1] Refer to the Introduction to Part II for identification of these cities and references to methods used to model urban meteorological conditions. This scenario models only concentrations for Farmington, New Mexico.

[2] The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency is investigating this question and will be used to inform further impact analysis.

[3] Stacks are 500 feet high, have an exit diameter of 30.3 feet, mass flow rates of 2.6 x 10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

[4] These efficiencies were hypothesized as reasonable estimates of current industrial practices.

Table 7-3 lists the amounts of the five criteria pollutants emitted by each of the four facilities. In all four cases, most emissions come from the plants rather than the mines. The largest single contributor to total emissions is the power plant for all pollutants except HC, in which case the Synthoil plant has the largest emissions. For all five pollutants, the Synthane plant has the smallest total emissions.

7.2.3 Impacts

A. Impacts to 1980

1. Pollution from Facilities

Construction of the hypothetical Lurgi gasification plant will begin in 1977, and the plant will become operational in 1980. Few air quality impacts are associated with the construction phase of this plant or with those coming on-line by 1990 or 2000, although construction processes may increase windblown dust which currently causes periodic violations of 24-hour ambient particulate standards.

Table 7-4 summarizes the concentrations of four pollutants predicted to be produced by the Lurgi plant and its supporting surface mine. These pollutants (particulates, SO_2, NO_2, and HC) are regulated by federal and New Mexico state ambient air quality standards (also shown in Table 7-4). Based on this data, the typical concentrations associated with the plant or the plant and mine combination, when added to existing background levels, will be well below federal and state standards. However, the peak concentration produced by the plant and mine combination will violate New Mexico's 24-hour NO_2 standard.[2]

Table 7-4 also lists the Non-Significant Deterioration (NSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e.,

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[1] The power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

[2] Potential air impacts are subject to the New Mexico state permit review system, which does not allow any facility development that threatens applicable state standards. If the operation of a plant will violate state standards, construction can be halted, and/or the plant may be required to install pollution control equipment.

TABLE 7-3: EMISSIONS FROM FACILITIES[a]
(pounds per hour)

Facilities[b]	Particulates	SO_2	NO_x	HC	CO_2
Electrical Generation[c]					
Mine	17	11	166	17	87
Plant	5,020	9,760	18,900	524	1,744
Lurgi					
Mine	8	5	68	8	41
Plant	434	469	2,810	58	375
Synthane					
Mine	7	5	63	7	38
Plant	805	327	1,475	30	196
Synthoil					
Mine	10	7	92	11	56
Plant	755	1,183	5,769	1,668	227

CO_2 = carbon dioxide
HC = hydrocarbons
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

[a] These levels of emissions would violate several New Mexico State New Source Performance Standards.

[b] The Lurgi and Synthane gasification plants are 250 million standard cubic feet per day facilities with three emissions stacks at each plant. The Synthoil plant produces 100,000 barrels per day and has 24 stacks. A detailed description of each plant is contained in the Energy Resource Development Systems description to be published as a separate report in 1977.

[c] Assuming 99-percent electrostatic precipitators efficiency and 80 percent SO_2 scrubber efficiency. The SO_2 scrubber is also assumed to remove 40 percent of oxides of nitrogen.

areas with air quality better than that allowed by ambient air standards).[1] "Class I" is intended to designate the cleanest

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[1] Non-Significant Deterioration standards apply only to particulates and sulfur dioxide.

TABLE 7-4: POLLUTION CONCENTRATIONS FROM LURGI PLANT AND MINE (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]					Standards[b]				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	Farmington	Primary	Secondary	New Mexico	Class I	Class II
Particulates										
Annual	40		0.1	0.6	0	75	60	60	5	10
30-day	40		0.4	1.1				90		
7-day	40		2.6	21				110		
24-hour	40	1.0	4.0	30	0.5	260	150	150	10	30
SO_2										
Annual	26		0.7	0.7	0.1	80		52	2	15
24-hour	26	1.2	6.5	16	0.6	365		260	5	100
3-hour	26	5.0	30	61	0.9		1,300		25	700
NO_2[c]										
Annual	10		0.5	4.0	0.2	100	100	94		
24-hour	10	16	30	160	2.2			190		
HC[d]										
3-hour	Unknown	0.2	4.0	31	0.1	160	160	160		

HC = Hydrocarbons
NO_2 = Nitrogen Dioxide
SO_2 = Sulfur Dioxide

[a] These are predicted ground-level concentrations from the hypothetical Lurgi gasification facility and mine. Annual average background levels are considered to be the best estimate of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Farmington are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants that can be added to areas of relatively clean air, such as national parks. These standards are discussed in detail in Chapter 14.

[c] All NO_x from plant sources is assumed to be converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

areas, such as national parks and forests.[1] Peak concentrations attributable to the Lurgi Plant or the plant and mine combination do not exceed Class II allowable increments. However, the short-term (24-hour or less) Class I increments for both particulates and SO_2 are exceeded.

Since the plant exceeds Class I increments, it would have to be located a sufficient distance from any Class I area to allow dilution of emissions by atmospheric mixing to required levels prior to their reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas.[2] Current Environmental Protection Agency (EPA) Regulations would require a minimum buffer zone of 10 miles between the Lurgi plant and a Class I area boundary.[3] No proposed Class I areas are within 10 miles of the plant site, but the Chaco Canyon National Monument, a potential Class I area, is about 20 miles to the southeast (Figure 7-3).

2. Pollution from the Town

The population of Farmington is expected to increase from 27,300 (1975) to 30,800 by 1980.[4] This population increase will

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[1] The Environmental Protection Agency initially designated all Non-Significant Deterioration areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class II. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

[2] Analysis of buffer zone requirements is based on the potential of many western areas to become Class I, either by redesignation or by Congressional requirement. Estimated sizes of buffer zones are based on dispersion modeling.

[3] Note that buffer zones around energy facilities will not be symmetrical. This is largely attributable to the windrose; that is, to the pattern and strength of areal winds which vary by location and season. Hence, the direction which Non-Significant Deterioration areas are located from energy facilities will be critical to the size of the buffer zone required.

[4] See Section 7.4.3.

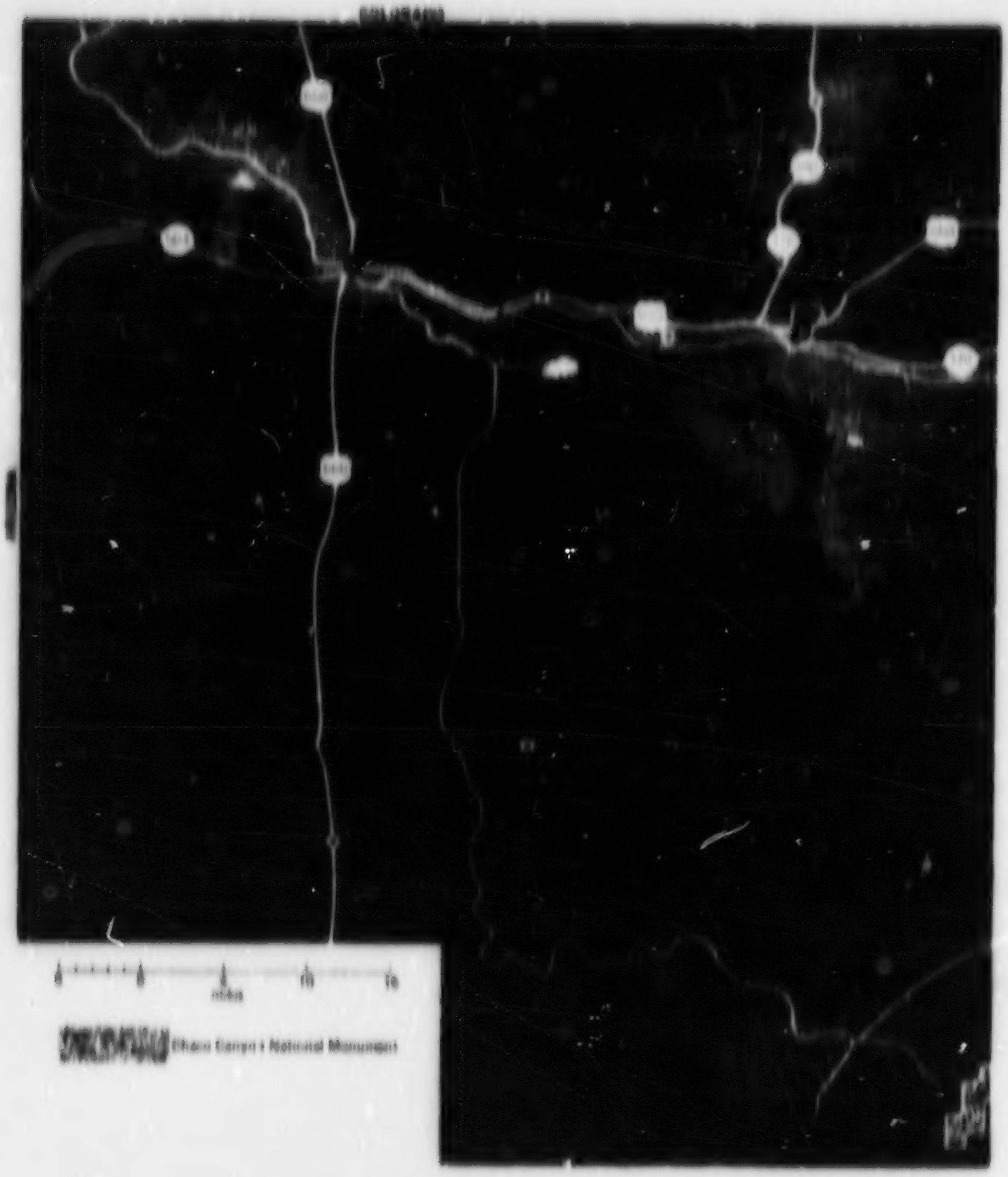

FIGURE 7-3: AIR IMPACTS OF ENERGY FACILITIES IN THE NAVAJO/FARMINGTON SCENARIO

contribute to increases in pollution concentrations due solely to urban sources. Table 7-5 shows predicted 1980 concentrations of the five criteria pollutants in the center of town and at a point 3 miles from the center of town.

When concentrations from urban sources are added to background levels and concentrations from the Lurgi Plant (given in Table 7-4), annual particulate levels exceed the federal secondary standard, and 3-hour HC levels exceed the federal and New Mexico standards.[1] Moreover, concentrations of particulates (30-day, 7-day, and 24-hour), SO_2 (annual), and NO_2 (annual and 24-hour) approach the most restrictive federal or state standard.

B. Impacts to 1990

1. Pollution from Facilities

Two new facilities are hypothesized to be constructed by 1990 in the Navajo/Farmington area. A power plant will become operational in 1985, and a Synthane gasification plant will become operational in 1990. Tables 7-6 and 7-7 summarize typical and peak concentrations of the five criteria pollutants after both plants become operational. Peak concentrations from both plants will violate New Mexico's ambient air standard for 24-hour NO_2 levels. No other federal or state ambient standard will be violated by these facilities and their associated mines.[2]

These facilities do exceed several allowable increments for NSD. Impacts from the power plant appear the most severe; both typical and peak concentrations will exceed some NSD increments. Class I and Class II 24-hour particulate levels will be exceeded by the peak concentrations from the plant. Peak concentrations from the plant will also exceed Class I increments for all three SO_2 averaging times, and typical concentrations will exceed the 24-hour SO_2 level. Peak concentrations from the Synthane plant

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[1] Hydrocarbon standards are violated regularly in most urban areas.

[2] Interactions of the pollutants from the plants are minimal because they have been (hypothetically) sited 6 miles apart. If the wind blows directly from one plant to the other, plumes will interact. However, the resulting concentrations will be less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentrations). The Lurgi plant is too far away to affect peak concentrations. If the plants were closer, the probability of interactions would increase. Sensitivity analysis of this siting consideration will be done during the remainder of the study.

TABLE 7-5: POLLUTION CONCENTRATIONS AT FARMINGTON

Pollutant Averaging Time	Concentrations[a]							Standards[b]		
		Mid-Town Point			Rural Point					
	Background	1980	1990	2000	1980	1990	2000	Primary	Secondary	New Mexico
Particulates										
Annual	40	[illegible]	[illegible]	[illegible]	4	6	6	75	60	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			90
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
24-hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	260	150	
SO_2										
Annual	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80		60
24-hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	365		260
3-hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		1,300	
NO_2[c]										
Annual	[illegible]	[illegible]	[illegible]	[illegible]	6	8	[illegible]	100	100	[illegible]
24-hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
HC[d]										
3-hour	Unknown	750	671	[illegible]	750	671	[illegible]	160	160	160
CO										
8-hour	Unknown	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10,000	10,000	
1-hour		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40,000	40,000	[illegible]

CO = Carbon Monoxide
HC = Hydrocarbons
NO_2 = Nitrogen Dioxide
SO_2 = Sulfur Dioxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 50 percent of NO_x from urban sources is converted to NO_2. Refer to the introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 7-6: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION
(micrograms per cubic meter)

[illegible]

TABLE 7-7: POLLUTANT CONCENTRATIONS FROM SYNTHANE GASIFICATION PLANT/MINE COMBINATION (micrograms per cubic meter)

	Concentrations[a]					Standards[b]				
			From			Ambient			Non-Significant Deterioration	
Pollutant-Averaging Time	Background	Typical	Plant	Plant and Mine	[illegible]	Primary	Secondary	New Mexico	Class I	Class II
Particulates										
annual	40	[illegible]	[illegible]	[illegible]	[illegible]	75	60	[illegible]	5	[illegible]
24-hour		1.7	[illegible]	[illegible]	[illegible]	260	150	[illegible]	10	30
SO_2										
annual	20	[illegible]	[illegible]	[illegible]	[illegible]	80		[illegible]	2	15
24-hour		[illegible]	[illegible]	[illegible]	[illegible]	365		[illegible]	5	100
3-hour			[illegible]	[illegible]	[illegible]		1,300		25	700
NO_2[c]										
annual	10	14.7	[illegible]	[illegible]	[illegible]	100	100	[illegible]		
HC[d]										
3-hour	Unknown	7.4	[illegible]	[illegible]	[illegible]	160	160	[illegible]		

HC = Hydrocarbons
NO_2 = Nitrogen Dioxide
SO_2 = Sulfur Dioxide

[a] These are predicted ground-level concentrations from the hypothetical synthane gasification plant and mine. [illegible]

[b] "Primary and secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. [illegible] Refer to the Introduction to Part II.

[c] It is assumed that all NO_x from plant sources is converted to NO_2.

[d] The 3-hour HC standard is measured at 6-9 a.m.

and associated mine will also violate at least one Class I standard for particulates and SO_2.

These NSD violations would require buffer zones between each plant and any Class I area. Current, EPA regulations would require the largest buffer zone (50 miles) for the power plant. The Chaco Canyon National Monument, a potential Class I area, is only 20 miles away. If it would be redesignated Class I, NSD requirements would prohibit the power plant from operating, given these emission levels. The buffer zone for the Synthane plant is less than 5 miles.

2. Pollution from the Town

Farmington's predicted population increase to 37,100 by 1990 will cause urban pollutant concentrations to reach the levels shown in Table 7-5. Combined with background levels, the 1990 concentrations will violate the federal secondary standard for annual particulate levels and New Mexico's 24-hour NO_2 and 3-hour HC standards. (As discussed earlier, the particulate and HC standards will have been violated by 1980.) These concentrations also approach either a federal secondary or New Mexico standard for 30-day, 7-day, and 24-hour particulate levels and annual SO_2 levels. The HC violation, which will exceed New Mexico's standard by a factor of seven, appears the most severe because it increases the likelihood of oxidant formation and photochemical smog.

C. Impacts to 2000

1. Pollution from Facilities

One new facility, a Synthoil liquefaction plant, will become operational between 1990 and 2000. Table 7-8 lists typical plant concentrations, peak plant concentrations, and peak combined concentrations from the plant and surface mine. These data show that the only violation from the Synthoil facilities (plant or plant/mine combination) will be HC emission levels, which are more than 175 times greater than New Mexico's standard.[1]

Peak concentrations from the Synthoil plant will exceed Class I NDS increments for 24-hour particulate and all three SO_2 increments. In addition, typical concentrations from the

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[1] Interactions between the new Synthoil plant and the Lurgi, electrical generation, and Synthane plants will increase annual peak concentrations near the power plant. However, these increases will be very small (less than 1 microgram for sulfur dioxide and nitrogen oxides) and thus will not violate any standards.

TABLE 7-6: POLLUTION CONCENTRATIONS FROM SYNTHOIL LIQUEFACTION PLANT/MINE COMBINATION (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations^a					Standards^b				
	Background	Typical	Peak			Ambient			Non-Significant Deterioration	
			Plant	Plant and Mine	Farmington	Primary	Secondary	New Mexico	Class I	Class II
Particulates										
Annual	40		1.3	1.6	0.2	75	60	60	5	10
30-day			2.6	2.8	0.4					
7-day			8.8	5.4	0.6					
24-hour		6	16	27	1.6	260	150	150	10	30
SO_2										
Annual	20		1.2	1.2	0.1	80		40	2	15
24-hour		22	20	20	2.2	365		260	5	100
3-hour		55	126	126	2.6		1,300		25	700
NO_2^c										
Annual	10		7.3	7.9	1.1	100	100	[illegible]		
24-hour		31	85	126	20			150		
HC^d										
3-hour	unknown	126	21,500	21,500	7.3	160	160	[illegible]		

HC = Hydrocarbons
NO_2 = Nitrogen Dioxide
SO_2 = Sulfur Dioxide

[a] These are predicted ground-level concentrations from the hypothetical Synthoil liquefaction plant and mine. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Farmington are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These standards are discussed in detail in Chapter 10.

[c] It is assumed that all NO_x from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

plant will exceed the 24-hour SO_2 increment. These concentrations would require a 16-mile buffer zone between the plant and any Class I area.

2. Pollution from the Town

Farmington's population will increase to 40,600 by the year 2000, and increased pollution concentrations will be associated with this growth (Table 7-5). These increases will exceed two additional ambient standards beyond those violated by population increases in 1990 (New Mexico's 30-day and 7-day particulate standards). Further, 24-hour particulate levels will be virtually equal to federal secondary standards.

7.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories of potential impacts are sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

A. Sulfates

Very little is known about sulfate concentrations likely to result from western energy development. However, one study suggests that for oil shale retorting, peak conversion rates of

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analyzed during the remainder of the project. See: Hazardous Materials Advisory Committee, Nitrogenous Compounds in the Environment, U.S. Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

SO_2 to sulfates in plumes is less than 1 percent.[1] Applying this ratio to plants in the Navajo scenario results in peak sulfate concentrations of less than 1 μg/m³. This level is well below EPA's suggested danger point of 12 μg/m³ for a 24-hour average.[2]

B. Oxidants

Oxidants (including such compounds as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and bromine) are a criteria pollutant which can be emitted from sources or formed in the atmosphere. For example, oxidants can be formed when hydrocarbons combine with oxides of nitrogen. Present knowledge of the conversion processes that form oxidants does not allow predictions of concentrations from power or liquefaction plants. However, the relatively low peak HC concentration from the power plant and its associated mine (78 μg/m³) suggests that these sources, alone, will not create an oxidant problem. More likely, any oxidant problem would result from the combination of background HC and the high levels of NO_2 emitted in the power plant plume. Since background HC levels are unknown, the extent of this problem has not been predicted.

In only one of several cases investigated[3] did coal gasification plant emissions result in oxidant levels that exceeded Federal standards. Since these cases are not comparable to the Lurgi and Synthane facilities hypothesized in this scenario, levels of oxidants formed from the combination of HC and NO_2 were not predicted. However, HC concentrations in this scenario are much smaller than those found in the one case in which standards were violated. Since the NO_2 levels are about equal, violation of oxidant concentrations from the gasification facilities in this scenario are not expected. This is not the case for the Synthoil plant, which produces peak HC concentrations about 150 times greater than the federal standard. Since NO_2 is emitted in the plume, violation of oxidant standards may result.

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[1] Nordsieck, R., *et al*. *Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States*, Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975. This study assumed that sulfur dioxide (SO_2) in the plumes was converted to sulfate at the rate of 1 percent per hour independent of humidity, clouds, or photochemically related reaction intensity. Reported results indicate peak sulfate levels ranging from 0.1 to 1.6 percent of the corresponding peak SO_2 levels from oil shale retorting. Recent work in Scandinavia suggests that acid-forming sulfates arriving in Norway are complex ammonium sulfates formed by a catalytic and/or photochemical process which varies with the season.

[2] *Ibid*.

[3] Nordsieck, *et al*. *Reactive Air Pollutants*.

HC concentrations over Farmington, which are five times higher than the federal standard, are also likely to create an oxidant problem. Since oxidant formation may occur relatively slowly (i.e. one or more hours), this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Fine Particulates

Fine particulates (those less than 3 microns in diameter) are primarily ash and coal particles emitted by the plants.[1] Current information suggests that particulate emissions controlled by ESP have a mean diameter of less than 5 microns, and uncontrolled particulates have a mean diameter of about 10 microns.[2] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles emitted by plant stacks. The high efficiency ESP's (99-percent removal) in this scenario reduce coarse particulate (>3 microns in diameter) emissions to the point that an estimated 95 percent (by weight) of the total particulate emissions are fine particulates. This percentage applies to the power plant and the Lurgi and Synthane gasification processes. However, since only half of the particulate emissions from the Synthoil plant are controlled, only about 25 percent of its emissions will be fine particulates. Health effects from fine particulates are discussed in Section 12.6.

D. Long-Range Visibility

One impact of very fine particulates (0.1-1.0 microns in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light, which reduces the contrast between an object and its background. As distance increases, the contrast level eventually falls below that required by the human eye to distinguish the object from the background. Estimates of visual ranges for this scenario are based on empirical relationships between visual distance and fine particulate concentrations.[1]

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[1] Fine particulates produced by atmospheric chemical reactions take long enough to form so they occur long distances from the plants.

[2] Fifty percent of the mass is contained in particles this diameter. Eppright, B.R., et al. A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station, Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Randian Corporation, 1974.

Visibility in the region of this scenario averages about 60 miles and may exceed 100 miles. The greatest reduction in average visibility will occur south of Farmington due to concentrations from sulfate and particulate emissions. As the facilities in this scenario become operational, average visibility will decrease to 59 miles by 1985, 57 miles by 1990, and 56 miles by 2000. Air stagnation episodes will cause substantially greater short-term reductions.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although ESP's will remove enough particulates for power plants to meet emission standards, stack plumes will still exceed the 20-percent opacity standard.[2] Thus, plumes would probably be visible at the stack exit and some distance downwind. Although no opacity standards exist for gasification or liquefaction plants, the Lurgi, Synthane, and Synthoil plants all have more than one stack which would produce plumes with greater than 20-percent opacity.

F. Cooling Tower Salt Deposition

The mist emitted from cooling towers has a high salt content and will deposit salts downwind of the towers. Estimated salt deposition rates for the four facilities in this scenario are shown in Table 7-9. These rates are relatively low and decrease rapidly beyond .07 mile. Some interaction of salt deposition from the various plants will occur. For example, the area midway between the power and Synthane plants will receive a cumulative total of 5.4 pounds per acre per year, and the area midway between the Lurgi and Synthoil plants will receive an

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[1] Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." *Atmospheric Environment*, Vol. 2 (September 1968), pp. 455-464. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

[2] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal unit's heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require removal of 99.9 percent of all plume particulates, which would increase electrostatic precipitator costs.

TABLE 7-9: SALT DEPOSITION RATES

Plant	Average Salt Deposition Rate[a] (pounds per acre per year)		
	0-.87 mile[b]	.87-7.5 miles	7.5-23 miles
Lurgi Gasification	3.9	0.8	0.2
Power Plant	23	4.9	0.9
Synthane Gasification	2.1	0.5	0.1
Synthoil Liquefaction	5.6	1.2	0.3

[a] Calculation assumed a wind speed equal to the annual average for Farmington and included the effects of humidity on evaporation.

[b] Diameter of circles bounding the area subject to the salt deposition rate.

average of about 2 pounds per acre per year. The effect of salt on the area will depend on soil conditions, rainfall, and existing vegetation.

G. Cooling Tower Fogging and Icing

Fogging and icing potentials in the Farmington area are generally low. Relative humidities above 95 percent occur only three or four times per year, and heavy fog (visibility reductions to .25 mile or less) occurs on the average about 8 days per year. Hence, cooling towers are likely to induce only slight increases in fog. Similarly, Farmington experiences freezing temperatures less than 20 percent of the year. Coupled with the relatively low humidities in the area, cooling towers will only slightly increase ice accumulations.

7.2.5 Summary of Air Impacts

A. Air Quality

Four new facilities are projected for the Navajo/Farmington scenario by the year 2000. The only federal ambient standard violated by these facilities is HC, which will be greatly exceeded by the Synthoil plant. New Mexico's 24-hour NO_2 standard will be violated by the Lurgi, electrical generation, and Synthane plants.

Each of the facilities will violate several PSD allowable increments. Peak concentrations from the power plant will exceed Class II increments for 24-hour particulates and all Class I SO_2 increments. In addition, average concentrations from the plant will violate one short-term SO_2 increment. Peak concentrations from the Lurgi, Synthane, and Synthoil plants will violate Class I increments for 24-hour particulates and at least two of the SO_2 increments. Because of these violations, each of the facilities will require buffer zones. The largest is required for the power plant (50 miles), followed by Synthoil (16 miles), Lurgi (10 miles), and Synthane (5 miles).

Population increases in Farmington will add to and create pollution problems. Current violations of annual particulate and HC levels will be exacerbated by increased concentrations due to urban sources. By 1990, New Mexico's 24-hour NO_2 standard will be violated, and by 2000, New Mexico's 30-day and 7-day particulate standards will be violated.

Several other categories of air impacts have received only preliminary attention. Our information to date suggests that oxidant and fine particulate problems are likely to emerge, largely owing to emissions from the Synthoil plant. Plumes from the stacks at all facilities will be visible and, in the case of the power plant, may exceed the 20-percent opacity standard. Average long-range visibility will be reduced from 60 miles to about 56 miles by the year 2000.

B. Alternative Emission Controls

Pollution concentrations from the power plant would vary if emission control systems with other efficiencies were used. For example, Table 7-10 gives SO_2 pollution concentrations which would result if the plant used only enough control to meet most New

TABLE 7-10: CONCENTRATIONS FROM MINIMAL EMISSION CONTROLS[a]
(micrograms per cubic meter)

SO_2 Averaging Time	Concentration	Standards		
		Primary	Secondary	New Mexico
Annual	13	80		44
24-hour	260	365		220
3-hour	1,816		1,300	

SO_2 = sulfur dioxide

[a] These are maximum concentrations which assume 20-percent SO_2 removal, which would meet the federal New Source Performance Standard of 1.2 pounds of SO_2 per million Btu's heat input.

Source Performance Standards; that is, if the plant removed only 20 percent of the SO_2 rather than the 80 percent currently hypothesized in this scenario.[1] These data show that resulting concentrations would violate either federal or New Mexico standards for each averaging time.

To meet all PSD Class II increments, alternatives are for the plants to increase the efficiency of emission controls or to reduce total plant capacity. Table 7-11 shows that 70-percent SO_2 removal and 99.5-percent particulate removal would be required to meet all allowable Class II increments.[2] Alternatively, the plant could meet Class II requirements by reducing capacity to 2,500 MWe.[3]

C. Data Availability

Availability and quality of data have limited the estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials in this chapter. Expected improvements in data and analysis capacities include:

1. Improved understanding of areawide pollutant dispersion in the San Juan Basin by monitoring currently being conducted under the auspices of the EPA.
2. Improved understanding of pollutant emissions from electrical generation, gasification, and liquefaction. This includes the effect of pollutants on visibility.
3. More information on the amounts and reactivity of trace elements from coals for alternative conversion processes would improve estimates of fallout and rainout from plumes.

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[1] These efficiencies would probably not meet the NSPS opacity standard. NSPS limit pollution emissions from stationary sources. Different regulations apply to different sources. NSPS do not exist for gasification and liquefaction plants. The Lurgi, Synthane, and Synthoil plants meet all Class II increments in this scenario.

[2] Seventy-percent sulfur dioxide removal is technologically feasible and 99.5-percent particulate removal appears feasible. More attention will be paid to technological feasibility of highly efficient control systems during the remainder of the project.

[3] This projection assumes concentrations are directly proportional to megawatt output.

TABLE 7-11: ALTERNATIVES FOR MEETING CLASS II INCREMENTS

Pollutant Averaging Time	Required Emission Removal (%)	Plant Capacity (MWe)
SO_2		
Annual	10	>3,000
24-hour	70	>3,000
3-hour	70	>3,000
Particulates		
Annual	96.3	>3,000
24-hour	99.5	2,500

MWe = megawatts-electric > = is greater than
SO_2 = sulfur dioxide

7.3 WATER IMPACTS

7.3.1 Introduction

Energy resource development facilities in the Navajo/Farmington scenario are sited in the San Juan River Basin, a subbasin of the Colorado River. The major water source for this development is the San Juan River (see Figure 7-4). The New Mexico portion of the San Juan Basin is arid, and water supplies are limited. Within most of the basin, annual rainfall is generally 10 inches or less, and snowfall is approximately 24 inches.

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

7.3.2 Existing Conditions

A. Groundwater

The aquifers of greatest significance to the scenario area are:[1] and alluvial aquifer system along the San Juan River and Chaco Wash and their tributaries; a shallow bedrock sandstone aquifer in the Pictured Cliffs Formation; and a deep bedrock sandstone aquifer in the Morrison Formation.

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[1] The entire New Mexico portion of the San Juan Basin was declared an underground basin in July 1976 by the State Engineer. Uses of the basin are subject to regulation as an aquifer of significance to water supply.

miles
Navajo Indian Irrigation Project
Water Line and Pumping Station

FIGURE 7-4: SURFACE WATER FEATURES AND WATER IMPACTS AT NAVAJO/FARMINGTON

Recharge of alluvial aquifers depends on stream flow; therefore, when associated with intermittent streams, alluvial aquifers are unreliable as supply sources for large water users. However, these aquifers are usually satisfactory as water sources for livestock and domestic purposes.

Water quality in the alluvial aquifer associated with Chaco Wash is relatively poor (contains up to 3,000 milligrams per liter [mg/ℓ] of total dissolved solids [TDS]. Water quality in the alluvial aquifer of the San Juan River is probably somewhat better because the aquifer is recharged by a perennial rather than an intermittent stream.

The Pictured Cliffs sandstone aquifer is about 100 feet thick and lies about 30 feet below the deepest minable coal seam. Its yield is low (generally about 10 gallons per minute), and the water is of poor quality. The TDS content is usually above 1,000 mg/ℓ and ranges as high as 75,000 mg/ℓ.[1] Recharge to the aquifer is estimated to be about 200 acre-feet per year (acre-ft/yr).

The Morrison sandstone aquifer is about 900 feet thick and, in the scenario area, occurs at a depth of about 5,000 feet. Little is known about the productivity and water quality of this aquifer.

B. Surface Water

All the southern tributaries of the San Juan River, including Chaco Wash and its tributaries, are ephemeral. Approximately 88 percent of the average annual water supply in the basin results from flow from the Colorado portion of the drainage basin.[2]

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[1] Forty-nine water samples from the Pictured Cliffs sandstone aquifer yielded an average total dissolved solids (TDS) content of 25,442 milligrams per liter (mg/ℓ). A sample from the alluvial aquifer of the Chaco River had a TDS content of 2,603 mg/ℓ. U.S., Department of the Interior, Bureau of Reclamation. *Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement*, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, pp. 2-37 and 2-38.

[2] This inflow from Colorado helps to explain why New Mexico's entitlement is somewhat less than the total available water leaving the state. The San Juan actually contributes about 17 percent of the flow at Lees Ferry, the point at which Upper Basin flow is measured.

Allocation and control of water resources in the San Juan River currently involves a number of treaties and basinwide compacts which include state and federal jurisdictions. These are the: Colorado River Compact;[1] Upper Colorado River Basin Compact;[2] Mexico Treaty of 1944;[3] and the laws of the State of New Mexico.

Under the Upper Colorado River Basin Compact, New Mexico is entitled to 11.25 percent of the water in the Colorado River to which Upper Basin states are entitled. However, the actual amount of water available to the Upper Basin states is not precisely known. Estimates range from 5.25 million to 7.5 million acre-ft/yr.[4] The Department of the Interior's Water for Energy Management Team estimates that the Upper Basin states have about 5.8 million acre-ft/yr to divide among themselves.[5] This would entitle New Mexico to 652,000 acre-ft/yr. However, the state of New Mexico claims that it is entitled to at least 703,000 acre-ft/yr, basing its claim on an estimate of 6.3 million acre-ft/yr.[6] Making some allowance for reuse, New Mexico uses an estimated 727,000 acre-ft/yr for planning purposes.[7] At present, there is sufficient water available in the San Juan River to meet any of these estimates.

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[1] Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[2] Upper Colorado River Basin Compact of 1948, 63 Stat. 31 (1949).

[3] Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

[4] Weatherford, Gary D., and Gordon C. Jacoby. "Impact of Energy Development on the Law of the Colorado River." _Natural Resources Journal_, Vol. 15 (January 1975), pp. 171-213; and Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[5] U.S., Department of the Interior, Water for Energy Management Team. _Report on Water for Energy in the Upper Colorado River Basin_. Denver: U.S. Department of the Interior, 1974.

[6] Colorado River Compact of 1922.

[7] U.S., Department of the Interior, Bureau of Reclamation _States' Comments, Westwide Study Report on Critical Water Problems Facing the Eleven Western States_. Denver, Colo.: Bureau of Reclamation, 1976.

TABLE 7-12: FLOW CHARACTERISTICS OF THE SAN JUAN RIVER

Location	Drainage Area (square miles)	20-Year Average Flow (1955-75)	Maximum Flow (cfs)	Minimum Flow (cfs)
Farmington	7,240	1,850 cfs 1,340,000 acre-ft/yr	68,000 (1927)	14 (1939)
Shiprock	12,900	1,848 acre-ft/yr 1,339,000 acre-ft/yr	80,000 (1929)	8 (1939)

cfs = cubic feet per second

Source: U.S., Department of the Interior, Geological Survey. *Surface Water Supply of the U.S., 1961-65*, Part 9, *Colorado River Basin*, Vol. 3, Water Supply Paper 1925. Washington, D.C.: Government Printing Office, 1970.

Baseline surface water flow in the scenario area varies considerably, and during low flow periods, withdrawals for energy use could be a substantial percentage of what is available. Flow characteristics of the San Juan River at Shiprock and Farmington are shown in Table 7-12. Since 1962, the flow in the San Juan has been partially regulated by the Navajo Reservoir, which was built to supply the Navajo Indian Irrigation Project (NIIP). The maximum and minimum flows of record at Farmington and Shiprock occurred before the construction of Navajo Reservoir. Since that time, variations in flow have not been as extreme. The reservoir operating conditions are shown in Table 7-13. To meet

TABLE 7-13: OPERATING CONDITIONS FOR NAVAJO RESERVOIR

Maximum storage	6,085 feet above mean sea level 1,709,000 acre-feet
Minimum storage	5,990 feet above mean sea level 600,000 acre-feet
Normal operating range pre-NIIP[a]	6,025-6,050 feet above mean sea level
Minimum release September-April	450 cubic feet per second[b]
Minimum release May-August	700 cubic feet per second[b]

[a] The Navajo Indian Irrigation Project will require 330,000 acre-feet/year of which 226,000 acre-feet/year will be consumed for irrigation and by evaporation and 104,000 acre-feet/year will be returned.

[b] Model studies indicated that these minimum flows could not be met during 3 years using 1927-1961 flow data. Under these extreme events, discharges to the San Juan River may be less than 300 cubic feet per second to maintain minimum storage in the reservoir.

TABLE 7-14: PRESENT AND PROJECTED WATER ALLOCATIONS FOR THE SAN JUAN RIVER

DEPLETIONS (Nominal-at-site) (thousands of acre-feet/year)	1974	Future
Irrigation (Present)	83	83
Other (M&I, F&W & Rec., Mineral, etc.) (Present)	13	13
Hammond	8	10
San Juan-Chama	46	110
Navajo Reservoir Evap.	24	26
Hogback Expansion	2	10
Utah International Inc. (Four Corners)	25	39
Farmington M&I (increase)	0	5
Navajo Indian Irrigation	0	226
Navajo M&I Contracts		
N.M. Pub. Serv. Co. (San Juan)	5	16
Utah International Inc. (WESCO)	0	35
El Paso Natural Gas Co.	0	28
Other (Gallup)	0	8
Animas-La Plata	0	34
Irrigation	0	(14)
M&I	0	(20)
Mainstream Reservoir Evap. 520 x .1125	58	58
	264	701

Source: U.S., Department of the Interior, Bureau of Reclamation. _States' Comments, Westwide Study Report on Critical Water Problems Facing the Eleven Western States_. Denver, Colo.: Bureau of Reclamation, 1976.

the NIIP water demand, it will be necessary to use the entire operating range and all of the active storage.

All of the water allocated in the basin is not currently being used. However, proposed developments may create a demand that exceeds the total available supply. Present and projected water allocations are shown in Table 7-14. This table is based on New Mexico's position that the flow available in the Upper Colorado is 6.3 million acre-ft/yr and reuse of return flows makes an additional 24,000 acre-ft/yr available to New Mexico.

The largest future development is the NIIP, but water commitments for energy development are also substantial. If the Water for Energy Management team's estimate of 5.8 million acre-ft/yr is used to calculate New Mexico's portion of the Upper Colorado River water, only 671,000 acre-ft/yr would be available, in which case future depletions would exceed supply. This could lead to the reallocation of water currently allocated but not being used or the purchase of existing water rights for new uses.

The quality of water in the San Juan River, which will be the source of process water for the energy facilities in this scenario, is shown in Table 7-15 along with typical industrial water quality requirements and drinking water standards. Sediment yields from the Chaco Wash area are particularly high, approximately 2000 tons per square mile per year.[1]

Two existing power plants are located in the San Juan Basin in the vicinity of the Navajo/Farmington scenario. The San Juan Power Plant has a closed-loop water system and does not return effluent to the San Juan. However, the Four Corners Power Plant discharges from Morgan Lake into Chaco Wash. This plant also uses Morgan Lake, a 1,200-acre lake, as a cooling pond. When evaporative losses from the lake increase water salinity to levels unacceptable for plant use, the lake is flushed into Chaco wash and refilled from the San Juan River by pipeline. As reported by Arizona Public Service Company, the operator of the Four Corners plant, these intermittent discharges have an average TDS concentration of 3,000 mg/l and are somewhat alkaline (pH levels are often above 9.0).[2] In the future, the company will be required to reduce the TDS levels of water discharged to comply with state standards and regulations.

7.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements for energy facilities hypothesized for the Navajo/Farmington scenario are shown in Table 7-16. Two sets of data are presented. The Energy Resource Development System data are based on secondary sources including impact statements, Federal Power Commission docket filings, and

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[1] New Mexico, Environmental Improvement Agency, Water Quality Division, Water Quality Control Commission. San Juan River Basin Plan, Draft Report. Santa Fe, N.M.: New Mexico, Water Quality Control Commission, 1974.

[2] According to the New Mexico, Water Quality Control Commission. (San Juan River Basin Plan.)

TABLE 7-15: WATER QUALITY IN SAN JUAN RIVER FOR 1973[a,b]

Constituent	Farmington (mg/l)		Shiprock (mg/l)		Drinking Water Standards[c]	Typical Boiler Tolerance[d]
	Maximum	Time Weighted Average	Maximum	Time Weighted Average		
Calcium	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Magnesium	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Sodium	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Potassium	[illegible]	[illegible]	[illegible]	[illegible]		
Bicarbonate	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Sulfate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chloride	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Total Dissolved Solids	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hardness (Ca, Mg)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
pH	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Turbidity[h]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Total Coliform	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Dissolved Oxygen	[illegible]	[illegible]	[illegible]	[illegible]		
Sediment			[illegible]	[illegible]		

Ca = Calcium Mg = Magnesium ml = milliliters

JTU = Jackson Turbidity Units mg/l = milligrams per liter [illegible]

[a] U.S. Department of the Interior, Geological Survey. [illegible] Water Resources Data for New Mexico. Part 2. Water Quality Records. Albuquerque, N.M.: U.S. Geological Survey, [illegible].

[b] Chemical analyses of composites or daily samples.

[c] U.S. Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." [illegible] December [illegible].

[d] Recommended by American Water Works Association, Inc.

[e] U.S. Environmental Protection Agency. "National Secondary Drinking Water Regulations." Proposed Regulations. [illegible]

[f] Maximum of record.

[g] Minimum of record.

[h] In Jackson Turbidity Units.

[i] [illegible]

[j] Maximum turbidity units allowed as a monthly average. Jackson Turbidity Units are assumed to be equivalent to Turbidity Units in the standard using the Nephelometric Method.

[k] As the arithmetic mean of all samples examined per month using the membrane filter technique.

TABLE 7-16: WATER REQUIREMENTS FOR ENERGY FACILITIES

Use	Size	Requirement[a] (acre-feet per year)	
		ERDS[b]	WPA[c]
Power Generation	3,000 MWe	43,000	40,480
Coal Gasification (Lurgi)	250 MMscfd	7,460	5,630
Coal Gasification (Synthane)	250 MMscfd	10,100	9,020
Coal Liquefaction	100,000 bbl/day[f]	19,406	11,910

bbl/day = barrels per day.

ERDS = energy resource development system.

MMscfd = million standard cubic feet per day.

MWe = megawatts-electric.

WPA = Water Purification Associates.

[a] Requirements are based on an assumed load factor of 100 percent. Although not realistic for sustained operation, this load factor indicates the maximum water demand for these facilities.

[b] Chapter Three of White, Irvin L., *et al.* *Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c] From Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

recently published data accumulations[1] and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water use requirements and take into account the moisture content of the coal being used and local meteorological data.[1]

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[1] These Energy Resource Development Systems, which are forthcoming as a separate publication, are based on data drawn from: University of Oklahoma, Science and Public Policy Program. *Energy Alternatives: A Comparative Analysis*. Washington, D.C.: Government Printing Office, 1975; Radian Corporation. *A Western Regional Energy Development Study*, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

The use of the water required for energy facilities is shown in Figure 7-5. As indicated there, the greatest water use for all energy conversion technologies is for cooling. Solids disposal consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

In addition to the water requirements of the facilities, the coal mines that provide feedstock coal for the facilities will also require water. If reclamation of surface-mined lands includes irrigation, most of the water requirements for mining will be for reclamation (see Table 7-17).

As mentioned previously, the San Juan River is the only reliable source of surface water in the area; thus, it is assumed to be the source of water for the energy facilities included in this scenario. As shown in Figure 7-3, pipelines

TABLE 7-17: WATER REQUIREMENTS FOR RECLAMATION[a]

Mine	Acres Disturbed Per Year	Maximum Acres Under Irrigation	Water Requirement (acre-ft/yr)
Power	830	4,150	3,110
Lurgi	360	1,825	1,370
Synthane	360	1,825	1,370
Synthoil	660	3,300	2,475
Total	2,210	11,100	8,325

[a] Based on an irrigation rate of 9 inches per year for 5 years.

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[1] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

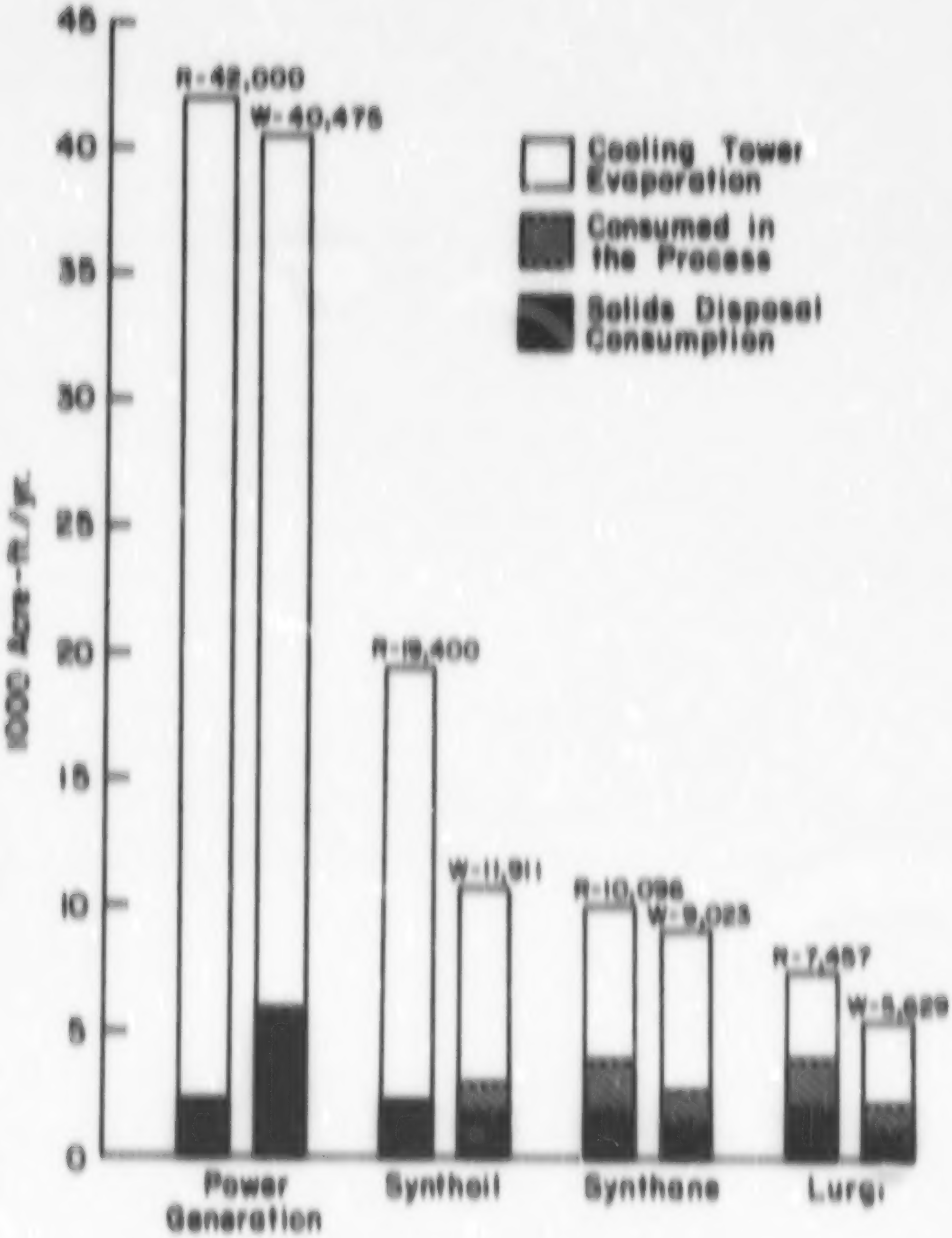

FIGURE 7-5: WATER CONSUMPTION USES FOR NAVAJO/FARMINGTON

will transport water from the San Juan River to the energy facilities. The rights to this water would have to be purchased from present holders. Groundwater supplies, the only alternative source, are not sufficient to support the postulated facilities.

B. Municipalities

The projected water needs of the expected increases in population are shown in Table 7-18. This table is divided into reservation and non-reservation requirements; reservation requirements are projected both with and without a new town. The water source for most towns is the San Juan River or its alluvial aquifer. These systems are expected to expand as the municipal demand increases. (A new town may have individual domestic wells or may pipe water from the San Juan River.)

7.3.4 Effluents

A. Energy Facilities

The quantities and types of waste streams from the energy facilities hypothesized for the Navajo/Farmington scenario are shown in Table 7-19. Fly ash and bottom ash disposal generate the largest quantities of residuals primarily because the coal contains 19 percent ash. Flue gas desulfurization also generates large quantities of residuals from power generation, even though Four Corners coal contains only 0.7 percent sulfur. Other residual quantities are insignificant.

All discharge streams from the facilities will be directed into clay-lined, on-site evaporative holding ponds. Run-off prevention systems will be installed in all areas that have a pollutant potential. Runoff will be directed to either a holding pond or a water treatment facility.

B. Municipalities

Rural populations are assumed to use individual on-site waste disposal facilities (septic tanks and drain fields), and the urban population will require waste treatment facilities. The current status of wastewater treatment facilities in the municipalities most affected by energy development activities is indicated in Table 7-20. Wastewater increases resulting from development-induced population increases are portioned as shown in Table 7-21. New wastewater treatment facilities adequate to meet the demands generated by these hypothetical developments and the associated population increases are being planned for all the impacted communities. These facilities will need to use the "best practicable" waste treatment technology to conform to 1983 standards and have allowance for recycling or zero discharge of

TABLE 7-18: EXPECTED INCREASE IN WATER REQUIREMENTS ABOVE 1975 BASE LEVEL[a]
(acre-feet per year)

Year	Non-Reservation			Reservation		
	Farmington[b]	Aztec[c]	Bloomfield[d]	Shiprock[e]	Kirtland-Waterflow[f]	Burnham Area[g] New Town
No New Town						
1980	1,440	180	35	440	150	-
1990	5,710	690	135	1,890	650	-
2000	8,840	1,080	210	2,540	860	-
New Town						
1980	1,440	180	35	440	150	390
1990	5,710	690	135	1,890	650	1,540
2000	8,840	1,080	210	2,540	860	1,820

[a] From telephone conversation, New Mexico Environmental Improvement Agency.

[b] 325 gallons per capita per day (gpcd)(Industrial included), 1972.

[c] 196 gpcd, 1972.

[d] 100 gpcd, 1972.

[e] 231 gpcd, 1972.

[f] 105 gpcd, 1973.

[g] 125 gpcd, estimate.

TABLE 7-19: [illegible]

	[illegible]	[illegible]			[illegible]			[illegible]			[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	–	–	–	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	–	–	–	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	–	–	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[a] [illegible]

[b] [illegible]

TABLE 7-20: WASTEWATER TREATMENT CHARACTERISTICS FOR TOWNS AFFECTED BY THE [illegible] SCENARIO[a]

Town	Type of Treatment	Design Capacity (Mgd)	Present Flow (Mgd)	Per Capita Flow (gcd)	Future Facilities
[illegible]	2 bar screens, 2 grit chambers, 2 primary clarifiers, 2 trickling filters, 2 secondary clarifiers, 1 digester	4.5	3.7	[illegible]	Design stage for [illegible] Mgd, [illegible]; 1985 expansion to 7.3 Mgd[b]
[illegible]	bar screen, grit chamber, primary clarifier, digester, trickling filter, secondary clarifier	.6	.40	100	Planning stage
[illegible]	bar screen, clarigester, trickling filter	.225	.12	[illegible]	[illegible], .3 Mgd[c]
[illegible]	bar screen, primary clarifier, 2 trickling filters, secondary clarifier	1	.40	80	Planning stage
[illegible]	septic field	–	–	–	None

gcd = gallons per capita per day
Mgd = million gallons per day

[a] Present data from telephone conversation with [illegible] Environmental Improvement Agency.

[b] From telephone conversation with [illegible] & Associates.

[c] From telephone conversation with [illegible] Engineering.

TABLE 7-21: EXPECTED INCREASES IN WASTEWATER FLOWS[a]

	Increased Flow above 1975 Level (million gallons per day)					
	Non-Reservation			Reservation		
Year	Farmington[b]	Aztec[c]	Bloomfield[d]	Shiprock[e]	Kirtland-Waterflow[e]	Burnham Area/New Town[e]
No New Town						
1980	0.50	0.20	0.03	0.14	0.10	-
1990	2.32	0.32	0.11	0.50	0.46	-
2000	3.50	0.48	0.17	0.70	0.50	-
New Town						
1980	0.50	0.20	0.03	0.14	0.10	0.32
1990	2.32	0.32	0.11	0.50	0.46	0.80
2000	3.50	0.48	0.17	0.70	0.50	1.06

[a] From telephone conversation, New Mexico Environmental Improvement Agency.

[b] 160 gallons per capita per day (gpcd).

[c] 100 gpcd.

[d] 91 gpcd.

[e] 86 gpcd.

pollutants to meet 1985 standards.[1] The 1985 standards could be met by using effluents for industrial process make-up water or by irrigating local farmland.

7.3.5 Impacts

A. Impacts to 1980

The Lurgi high-Btu (British thermal unit) gasification plant and its associated surface mine will be constructed and in operation by 1980.

1. Surface Mines

As noted previously, the Pictured Cliffs sandstone aquifer is about 30 feet below the deepest minable coal seam and would probably be the only aquifer affected by mining. Flow patterns in the aquifer may be disturbed by blasting required to open the Lurgi plant coal mine.

Surface-water drainage patterns will be affected by mine excavations, some of which will trap runoff. Unless these ponds are pumped out regularly, the impounded water may eventually percolate into the groundwater system or evaporate, but this is not expected to produce a significant impact. Losses in runoff due to mine excavations are not expected to be significant locally because area streams are ephemeral and water would quickly dry up in any case. This loss of runoff into tributaries of the Colorado River would not reduce the flow in the river to a great extent.

2. Energy Conversion Facilities

Construction activities at the power plant will remove vegetation and disturb the soil. These activities have an effect on surface-water quality. The major effect will be from increases in the sediment load of local runoff. Maintenance areas and petroleum products storage facilities will also be needed to support construction equipment. Areas for the storage of other construction-related materials (such as aggregate for a concrete batch plant) may be required as well. All these facilities have the potential for contaminating runoff. Runoff control methods will be instituted at all of these potential sources of contaminants; runoff will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water, although some of the water may be used for dust control.

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[1] Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

A well drilled into the Morrison sandstone aquifer will provide water for the construction of the Lurgi plant while the water supply pipeline is being built from the San Juan River to the plant site. Only about 400 acre-feet will be needed from the aquifer before the pipeline is completed, a small part of the total water supply available from this aquifer.

Holding ponds and runoff retention facilities will decrease runoff from the plant sites below present levels. This loss may decrease flow in the San Juan River, but the effect will be small and temporary.

3. Municipal Facilities

From the present to 1980, most urban growth will be absorbed by existing communities, and local groundwater systems will not be significantly affected. Additional demands will be made on surface-water supplies, but the overall increases should be small (see Table 7-18).

Municipalities must secure a permit to withdraw additional water from surface supplies in the area. As shown in Tables 7-20 and 7-21, wastewater treatment facilities will be operating at or exceeding design capacity in Farmington and Bloomfield by 1980. Unless new facilities come on-line to meet these requirements, some surface-water pollution may result from overloads and/or bypasses.

B. Impacts to 1990

During the 1980-1990 period, the power plant and the Synthane high-Btu gasification facility will be constructed and become operational. Population increases resulting from these developments may be accommodated by existing communities or by a new town on reservation lands.

1. Surface Mines

The three mines in operation by 1990 will affect the water quality of the Pictured Cliffs sandstone aquifer because, as indicated previously, it lies only about 30 feet below the lowest coal bed. Weathering and leaching of mine wastes and ash that are deposited in mined-out areas will probably result in poor quality water filtering into the aquifer. However, the low annual precipitation of the area lessens the potential seriousness of this problem. In any case, water quality in the aquifer is already poor (TDS from 49 wells average about 25,500 mg/ℓ and range from 1,000 to 75,000 mg/ℓ).

Groundwater seepage or storm-water runoff that pools in operational areas of mines will be recycled. The quality of water impounded in mined-out locations within the Navajo/

Farmington area should be approximately the same as the quality of water in natural streams.[1] These impoundments will not result in a significant loss of water to the Colorado River System. The mines will have encompassed approximately 7,800 acres by 1990. If it is found that runoff retention facilities are required for this area, approximately 130 acre-ft/yr of water would be withheld from the local watersheds.

2. Energy Conversion Facilities

Construction activities will increase greatly during the 1980-1990 period. Consequently the construction-related impacts described for the previous decade will also increase in magnitude.

The three plants in operation by 1990 will probably not significantly affect the quantity of recharge water fed to the Pictured Cliffs aquifer. The failure or inadequacy of liners in on-site holding ponds may result in the leakage of pollutants into the Pictured Cliffs aquifer. Since plant effluents will be contained within the plant sites, no other aquifer systems will be affected by 1980, and withdrawal from the Morrison aquifer will cease by then.

Changes in surface-water quality will occur primarily as a result of the combined water demands of all the energy development facilities. The water supply system may eventually have a salt-concentrating effect because it will remove water with a relatively low TDS content from the river basin. Consequently, some increase in TDS may be noticed at both Lake Powell and Lake Mead.[2] The TDS concentrations at Shiprock and at Imperial Dam will increase by approximately 7.1 and 2.9 mg/ℓ respectively.[3] These increases are estimated averages and could be higher at Shiprock during low-flow periods. The increases would probably not vary seasonally at the major reservoirs because of their large buffer capacity. The Utah Water Resources Laboratory of the University of Utah estimates that the annual economic cost of salinity ranges from $45,900 to $230,000 for each mg/ℓ increase in TDS.[1]

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[1] U.S., Department of the Interior, Bureau of Reclamation, Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

[2] Bureau of Reclamation, WESCO Project: FES. This statement calls for four 1,000 million standard cubic feet per day gasification plants to be operating under 1981 conditions.

[3] Ibid.

Some concentration of suspended solids (sediment) will occur downstream from the pipeline intakes if a gravel bed-perforated pipe intake filtration system is used. This system will remove only clear water, thus leaving most suspended particles in the San Juan River. At the plant sites, changes in surface-water quality will be negligible because of the small amount of runoff (0.1-0.2 inch per year) and the runoff control systems provided.

Plant effluents are not expected to significantly affect surface water qualities because of the use of discharge technology that meet the goals of the Federal Water Pollution Control Act Amendments of 1972.

3. Municipal Facilities

Neither growth of the existing communities nor establishment of a new town is expected to have much effect on groundwater quality or quantity. However, some increased municipal and industrial needs must be met from surface water.

As shown in Tables 7-20 and 7-21, the municipal wastewater loads will continue to stress the existing system. The 1976 design loads will be equalled or exceeded in Farmington, Aztec, Bloomfield, and Shiprock. Current expansion plans will provide adequate capacity in Farmington and Bloomfield if constructed on an appropriate schedule.

Runoff will be increased by the expansion of existing towns. This runoff is generally routed directly into major streams and will eventually augment flow in the San Juan River.

C. Impacts to 2000

The only major facilities to be added during the 1990-2000 decade are a Synthoil liquefaction plant and its associated coal mine. The mine will begin operation in 1999, and the plant will come on-line in 2000. Thus, the impacts associated with these facilities will be primarily related to construction during this decade.

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[1] Utah State University, Utah Water Research Laboratory, Colorado River Regional Assessment Study, Part 1, Executive Summary, Basin Profile and Report Digest, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975.

The water impacts to 2000 are expected to be qualitatively about the same as to 1990. Quantitatively, the impacts will be somewhat higher because of the cumulative effect of the three existing plants and because of the addition of the Synthoil plant. Population growth will also continue during the decade, resulting in additional water demands and wastewater treatment requirements.

D. Impacts After 2000

After the plants are decommissioned, the structures will remain. Although many areas will be reclaimed and revegetated, irrigation of the areas will ultimately cease. Subsequently, vegetation may be lost and erosion may increase. The berms around the ponds will also probably lose their protective vegetation and erode, and the berms may breach as a result. If this happens, the materials within the pond site will erode and enter the surface-water system. Although the salt materials from the evaporation ponds eventually will return to their original source, the San Juan River, concentrations may be high enough to cause localized damage to aquatic ecosystems. Likewise, the addition of trace materials and solids from the ash disposal and tailings ponds may have an adverse effect. The low precipitation in the scenario area will retard the transport of these materials.

The towns associated with the energy development will likely remain but populations will decline. The effects of increased storm-water runoff from urban areas and the associated introduction of contaminants into surface water will also remain unless the water is treated.

7.3.6 Summary of Water Impacts

The total surface-water requirement for the postulated energy facilities is as much as 102,700 acre-ft/yr, including water needs resulting from development-related population increases and the postulated new town development. Combined with other current and planned surface-water usage in the area, this demand may exceed New Mexico's total allotment from the San Juan Basin, depending on the value used to represent the dependable flow in the Colorado River at Lees Ferry.

A potential long-term groundwater pollution problem is pond leakage. Pond liners should forestall this problem during the life of the plants, but the materials are likely to leach through the liners eventually and enter the groundwater system.

Another possible impact following the cessation of maintenance activities is the eventual destruction of berms containing salts, ash, trace materials, sanitary sludge, and scrubber sludge. If concentrations of these materials enter surface water systems, both local biota and downstream water users might be affected.

Identification and description of several water impacts have been limited by available information. Missing data include detailed information about process streams (needed to identify the composition of discharges to settling ponds) and about the rate of movement of toxic materials through pond liners (needed to estimate the portions that might reach shallow aquifers). More quantitative information will be sought during the remainder of the project so that these potential impacts can be properly evaluated.

7.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

7.4.1 Introduction

San Juan County, the site of the hypothetical energy development proposed in the Navajo/Farmington scenario, is located in the extreme northwestern corner of New Mexico.

Understanding the many differences between Indians and non-Indians in the county is basic to an analysis of the social, economic, and political effects of energy development within the Navajo/Farmington area. In the analyses which follow, Indian and non-Indian and reservation and nonreservation impacts generally are treated separately. During the first year, secondary sources were relied on to understand these differences; however, field work currently under way in the Navajo/Farmington area is intended to add to the team's understanding and to sharpen the analyses undertaken during the remainder of the project.

7.4.2 Existing Conditions

Less than 6 percent of the land in San Juan County is privately owned. The Navajo and the Ute Mountain Reservations occupy approximately 60 percent of the county; another 4.8 percent is owned by the state, and 29.5 percent is owned by the federal government.

San Juan County's 1974 population was 61,700, 56 percent of which was located in the three cities of Aztec, Bloomfield, and Farmington. Population density countywide was 11.2 persons per square mile; outside the three cities, it was 4.9. Approximately 35 percent of the county's 1970 population was Indian, 96 percent living on the Navajo Reservation. Thirteen percent of the population either had Spanish surnames or used Spanish as their primary language. Less than 1 percent was Black. Except for a slight decline between 1960 and 1970, the county's population has been increasing over the past 35 years. Population in the three cities has also been increasing, and people have been somewhat more mobile than is generally the case in the western U.S.[1]

Housing in the county is relatively new, four-fifths of it having been built since 1950. Between 1970 and 1973, 739 new homes were constructed; 551 in 1973 alone. Mobile homes comprised about 12 percent of all the houses in Farmington.[2]

The median value of a single-family dwelling in the county was about $13,000 in 1970 ($21,000 in 1975 dollars); the median rent was $80 ($130 in 1975 dollars). Both were somewhat higher in Farmington: the median house value there was about $18,000, and the median rent was about $165.[3] In early 1976, the minimum price housing in Farmington was about $22,000, and the median was over $30,000. Rents ranged from $175 to about $260 per month.[4]

The county is governed by a board of commissioners. A substantial planning capacity has been developed within the County Planning and Research Department, which now has both a planner and assistant planner. Except for transportation and housing supply, the county seems to have an adequate infrastructure and service mix to accommodate additional population growth.[5] There is no countywide zoning ordinance at present. However, a land-use study is under way, the results of which are to be used by the commissioners to decide whether a zoning ordinance is needed.

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[1] In 1970, owner occupants of dwellings had been in their homes a median of 5.4 years and renters for 2.5 years. Of the 1970 population, 72.7 percent had lived in the same county in 1965.

[2] U.S., Department of Commerce, Bureau of the Census. _County and City Data Book: A Statistical Abstract Supplement_. Washington, D.C.: Government Printing Office, 1972; New Mexico, Bureau of Business and Economic Research. _Community Profile: Farmington, 1974-75_. Santa Fe, N.M.: New Mexico, Department of Development, 1974.

[3] _Ibid._

[4] Farmington (New Mexico) Chamber of Commerce. _General Information, January 15, 1976_. Farmington, N.M.: Chamber of Commerce, 1976.

[5] See Sickafoose, Paul W. _A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area_. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974; and Farmington Chamber of Commerce,

Shiprock is the only urban center on the San Juan County portion of the reservation.[1] It is unincorporated, has no established boundaries, and is governed by the Tribal Council. Public services are provided by the tribal, county, state, and federal governments. Water, sewer, and electrical services are provided generally only along the highway south from Shiprock. Health services are provided by the Public Health Service and the Bureau of Indian Affairs (BIA). Public safety is maintained by the Navajo and state police forces and the county sheriff. The BIA and the state of New Mexico construct and maintain the roads.

Farmington, the area's largest city, is governed by a four-member council, has a city manager, and has a professional planning capability. City services include water, sewers, electricity, police and fire protection, and recreation. There are no social assistance services apart from those provided jointly by the county and state.

According to the city planning department, most of the service delivery systems are currently operating at or near capacity. A recently completed status report identifies some $30 million worth of projects that are needed to absorb already anticipated population impacts.[2] In the view of both city and county officials, the primary need is construction and operating funds, not help in identifying and analyzing problems.

The other off-reservation cities, Aztec and Bloomfield, have mayor-council governments and a city manager. Except for electricity, services in both are the same as those provided by Farmington.

Although a major portion of the reservation is within San Juan County, the Navajos retain a separate identity as the Navajo Nation. While the Navajos govern themselves, there are numerous unanswered questions in Indian law that can affect energy development in the area. For example, the water rights of Indians generally[3] are in question. The applicability of state laws intended to regulate energy development, particularly environmental laws, is also unresolved.[1]

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[1] There are smaller, unincorporated communities in the Farmington/Shiprock corridor. These include Kirtland, Fruitland, and Waterflow.

[2] Farmington, New Mexico, City of. *Status Report, March 11, 1976*. Farmington, N.M.: City of Farmington, 1976.

[3] Pelcyger, Robert S. "Indian Water Rights, Some Emerging Frontiers," in Rocky Mountain Mineral Law Foundation. *Rocky Mountain Mineral Law Institute: Proceedings of the Twenty-First Annual Institute*, July 17-19, 1975. New York, N.Y.: Matthew Bender, 1975, p. 70.

Concerning its ability to absorb and serve the anticipated population increases, the tribe has been increasing its professional staff, particularly its capacity to plan for economic development. The Tribal Council, the legislative arm of tribal government, has also created specialized commissions to deal with revenue needs and environmentally related challenges. For example, the Navajo Tax Commission is studying the potential for establishing property taxes within the reservation as a means of funding traditional services provided by the Council. In addition, this Commission is involved in efforts to renegotiate existing royalty rates for mining activity on Navajo land because the tribe believes it did not receive equitable treatment in the past. Another special commission, the Navajo Environmental Protection Commission, was created in response to the Navajo's need for an independent environmental assessment, regulatory, and enforcement organization. This five-member commission has the authority to implement the environmental policy of the tribe, serves as a forum for environmental information collection, and considers adverse environmental impacts associated with potential development on the reservation.[2]

The area's non-reservation economy is characterized by its diversity as illustrated by the 1973 distribution of employment shown in Table 7-22. However, the reservation economy is still predominantly agricultural, and the unemployment rate among Indians is well above the county average shown in Table 7-23.

Farmington is the economic service center for northwestern New Mexico and thus contains a major portion of the available professional and supporting services for the various industrial and agricultural activities in the area. However, some supporting services are available in Aztec, Bloomfield, and Shiprock.

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[1] Will, J. Kemper. *Questions and Answers on EPA's Authority Regarding Indian Tribes.* Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1976.

[2] For a discussion of the development of Navajo Environmental Protection Commission and problems related to the Commission's attempts to implement its regulatory and assessment potential, see Cortner, Hanna J. *The Navajo Environmental Protection Commission and the Environmental Impact Statement.* Lake Powell Research Project Bulletin 37. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1976.

TABLE 7-22: EMPLOYMENT DISTRIBUTION IN SAN JUAN COUNTY, 1973

Industry	Employees	% of Employed
Total Civilian Work Force	21,193	
Total Employed	19,371	100
Agriculture	1,597	8.2
Manufacturing	1,754	9.1
Mining	1,803	9.3
Contract Construction	1,943	10
Transportation, Communications, and Utilities	2,015	10.4
Wholesale and Retail Trade	3,596	18.6
Finance, Insurance, and Real Estate	438	2.3
Government	3,439	17.8
Services and Miscellaneous	2,787	14.4
Total Unemployed	1,822[a]	

Source: State of New Mexico Department of Development, Economic Development Division.

[a] 8.2 percent of labor force.

Per-capita income in the county was $3,147 in 1973, which was below the average of $3,512 for the state as a whole.[1] For the Navajo Nation as a whole, the median per-capita income was $1,984 in 1969 and about $2,220 in 1973, well below the county and state averages.[2] Thus, relatively higher incomes off the reservation contrast sharply with low incomes among Navajos.

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[1] University of New Mexico, Bureau of Business and Economic Research. New Mexico Statistical Abstract, 1975. Albuquerque, N.M.: University of New Mexico, Bureau of Business and Economic Research, 1975, p. 50.

[2] U.S. Department of Commerce, Bureau of the Census. Census of Population: 1970; Subject Reports: Final Report PC(2)-1F: American Indians. Washington, D.C.: Government Printing Office, 1973.

7.4.3 Population Impacts

Employment data for both energy development[1] and the Navajo Indian Irrigation Project[2] are listed in Tables 7-23 and 7-24 and presented graphically in Figure 7-6.[3] Population increases are expected in both Indian and non-Indian areas (Table 7-25; Figures 7-7 and 7-8). In this analysis, population increases are assumed to be absorbed both by existing communities

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[1] Employment data for energy facilities are from: Carasso, M., _et al._ _The Energy Supply Planning Model._ San Francisco, Calif.: Bechtel Corporation, 1975.

[2] For discussions of the Navajo Indian Irrigation Project, see Morrison-Knudsen Company. _Navajo New Town Feasibility Overview._ Boise, Idaho: Morrison-Knudsen, 1975. Morrison-Knudsen's population projections of the project are from Bickefoose, Paul W. _A Socioeconomic Analysis of the Impact of New Highway_ Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, p. 178.

[3] Population impacts were determined using an economic base model, construction and operation employment data from Table 7-23, sets of secondary/basic employment multipliers which increase during the early years of energy development (Table 7-24), and population/employment multipliers which include wives working in service jobs (Table 7-25). The final component of population change was natural increase which was assumed to be: 0.8 percent annually from 1975 to 1990 and 0.5 percent thereafter for the Anglo population; and 2.5 percent from 1975 to 1985, 2.0 percent from 1986 to 1995, and 1.5 percent thereafter for the Navajo population. The Indian employment on energy projects was assumed to be one-half of the total through 1990 and 80 percent after 1990. All non-Navajos from outside San Juan County was assumed to be .64 through 1980, .86 from 1981-85, .76 from 1986-90, and .69 after 1990. Ninety percent of Navajo Indian Irrigation Project employment is assumed to be Navajo, 90 percent of which is assumed to be non-local to San Juan County. See U.S., Department of the Interior, Bureau of Reclamation. _Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement._ 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, pp. 3-173 to 3-178.

TABLE 7-23: NEW EMPLOYMENT IN SAN JUAN COUNTY FROM ENERGY DEVELOPMENT AND NAVAJO INDIAN IRRIGATION PROJECT, 1975-2000

Year	Energy Construction	Energy Operation	Navajo Indian Irrigation Project	Total
1975	0	0	0	0
1976	40	0	460	500
1977	250	0	570	820
1978	620	0	660	1,280
1979	1,120	270	810	2,200
1980	1,560	270	980	2,810
1981	2,890	550	1,190	4,630
1982	5,440	660	1,510	7,610
1983	6,880	940	1,600	9,420
1984	70	1,040	1,740	2,850
1985	820	2,130	1,780	4,730
1986	2,890	2,130	2,120	7,140
1987	4,890	2,400	2,140	9,430
1988	2,830	2,400	2,140	7,370
1989	0	3,270	2,140	5,410
1990	0	3,270	2,140	5,410
1991	0	3,270	2,140	5,410
1992	0	3,270	2,140	5,410
1993	30	3,270	2,140	5,440
1994	260	3,270	2,140	5,670
1995	1,010	3,270	2,140	6,420
1996	2,070	3,270	2,140	7,480
1997	2,380	3,270	2,140	7,790
1998	1,730	3,550	2,140	7,420
1999	640	4,180	2,140	6,960
2000	0	5,100	2,140	7,240

Source: Eickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, p. 178.

TABLE 7-24: ASSUMED SECONDARY/BASIC EMPLOYMENT MULTIPLIERS FOR NAVAJO/FARMINGTON SCENARIO, 1976-2000[a]

Date	Construction Phase Multipliers		Operation Phase Multipliers	
	Anglo	Navajo	Anglo	Navajo
1976	[illegible]	0.1		
1977	[illegible]	0.1		
1978	[illegible]	0.1		
1979	[illegible]	0.1	[illegible]	0.4
1980	[illegible]	0.1	[illegible]	[illegible]
1981	[illegible]	0.1	[illegible]	[illegible]
1982	[illegible]	0.1	[illegible]	[illegible]
1983	[illegible]	0.1	[illegible]	[illegible]
1984	[illegible]	0.1	[illegible]	[illegible]
1985	[illegible]	0.1	[illegible]	[illegible]
1986	[illegible]	0.1	[illegible]	[illegible]
1987	[illegible]	0.1	[illegible]	[illegible]
1988	[illegible]	0.1	[illegible]	[illegible]
1989	[illegible]	0.1	[illegible]	[illegible]
1990	[illegible]	0.1	[illegible]	[illegible]
1991	[illegible]	0.1	[illegible]	[illegible]
1992	0.7	0.1	[illegible]	0.85
1993-2000	0.7	0.1	[illegible]	0.9

Assumed Population/Employee Multipliers[b]		
Activity	Non-Navajo	Navajo
Construction	[illegible]	[illegible]
Operation	[illegible]	[illegible]
Service	[illegible]	[illegible]

[a] These values were determined by synthesizing materials from several sources and may be low for the non-Navajo population. See New Mexico State University, Department of Agricultural Economics and Agricultural Business, [illegible] New Mexico State University, Department of Agricultural Economics and Agricultural Business, pp. [illegible]; Morrison-Knudsen Company. Navajo New Town Feasibility [illegible]. Boise, Idaho: Morrison-Knudsen, [illegible]; Robbins, Lynn A. The Impact of Power Development on the Navajo Nation. Lake Powell Research Project Bulletin. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, [illegible]; U.S., Department of the Interior, Bureau of Reclamation. [illegible] Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, [illegible]; [illegible] for Business Services, [illegible]; U.S., Department of the Interior, Bureau of Reclamation. [illegible] Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, [illegible]. Navajo household [illegible] large on average considering single workers.

[b] Non-Navajo population multipliers are adapted from Mountain West Research. [illegible] Final Report. Washington, D.C.: Old West Regional Commission, [illegible].

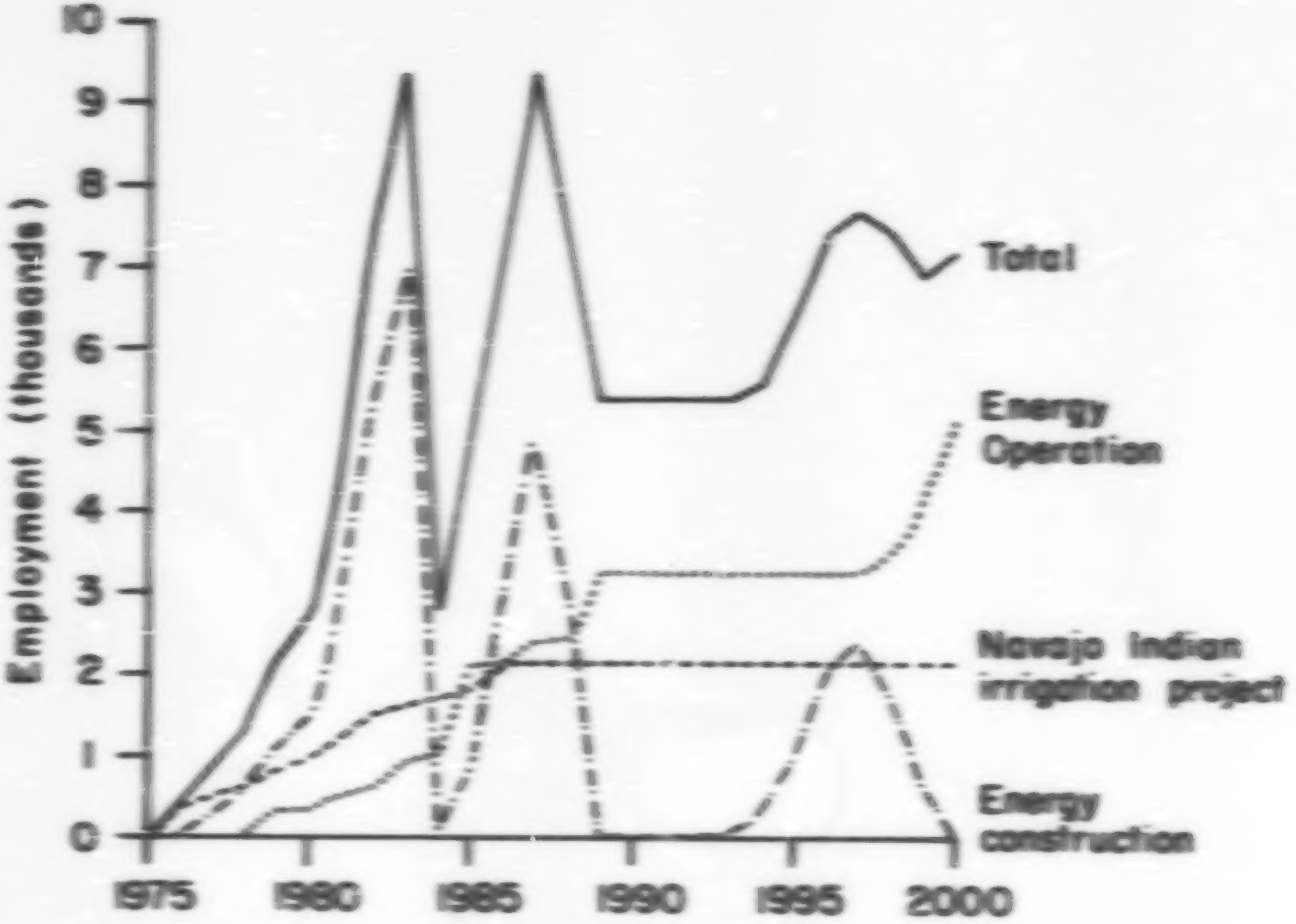

FIGURE 7-6: NEW EMPLOYMENT IN SAN JUAN COUNTY FROM ENERGY DEVELOPMENT AND NAVAJO INDIAN IRRIGATION PROJECT, 1975-2000

TABLE 7-25: POPULATION ESTIMATES FOR SAN JUAN COUNTY[a]

Location	1975	1980	1983	1985	1987	1990	1995	2000
Reservation								
Shiprock	4,000	5,300	8,200	6,967	8,800	8,100	8,900	11,300
New Town	0	4,700	6,000	8,066	10,000	12,000	12,000	12,000
Other Navajo	21,000	23,600	36,900	29,100	36,400	30,600	34,800	47,600
Total	25,000	32,900	51,100	43,060	55,200	50,700	55,700	70,900
Non-Reservation								
Farmington	27,300	30,800	38,600	34,100	40,700	37,100	38,600	40,600
Aztec	5,500	6,200	7,806	6,900	8,150	7,500	7,800	8,200
Bloomfield	2,100	2,350	2,350	2,600	3,100	2,850	2,950	3,100
Other	1,800	1,950	2,550	2,300	2,550	2,450	2,550	2,600
Total	36,700	41,300	51,900	45,900	54,000	49,900	51,900	54,500
County Total	61,700	74,200	103,000	88,900	109,200	100,600	107,600	125,400

[a] Given the assumptions of the scenario, these estimates have an error range of about ±30 percent, which is then incorporated in further projections below.

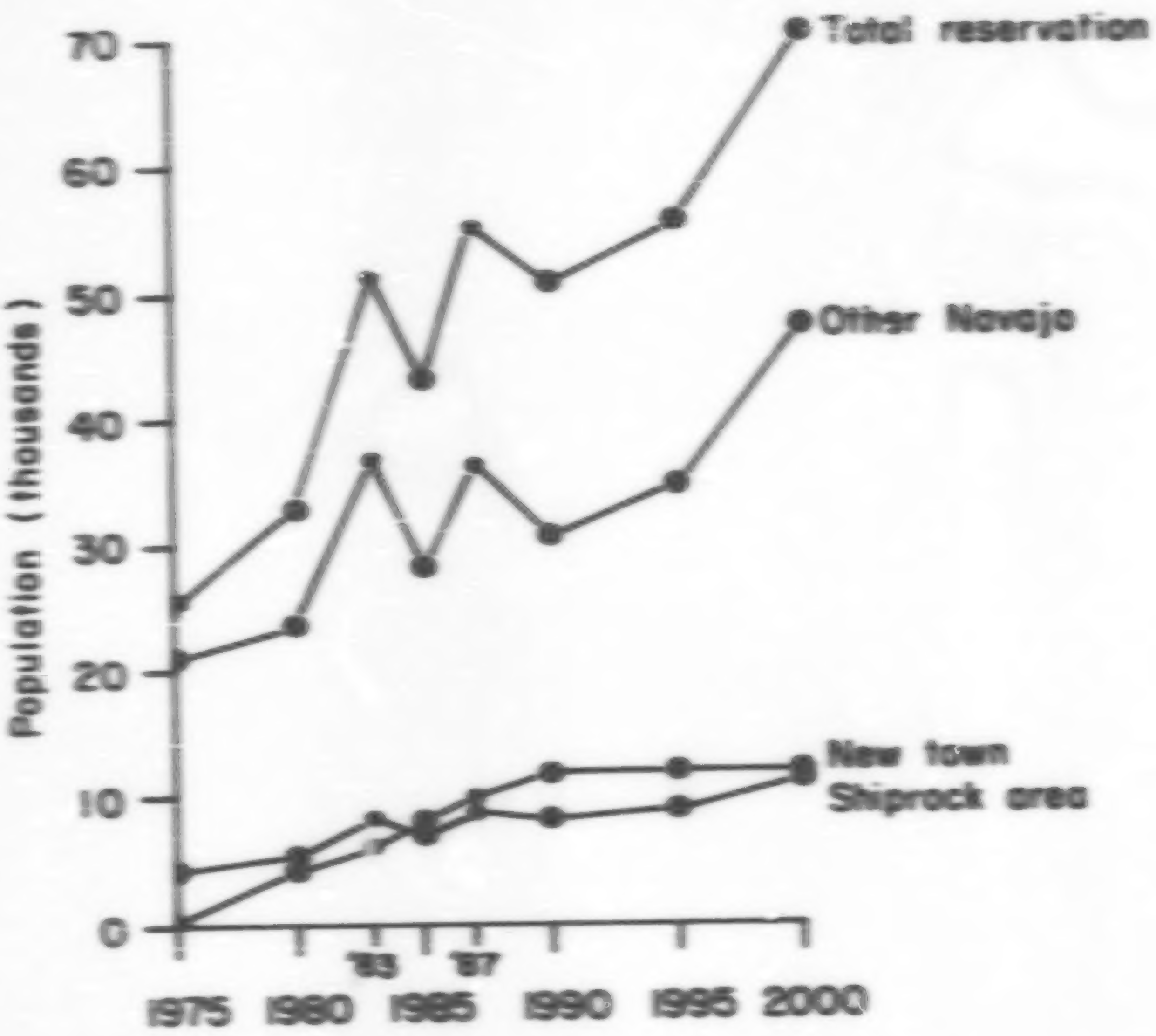

FIGURE 7-7: POPULATION ESTIMATES FOR NAVAJO RESERVATION PORTION
OF SAN JUAN COUNTY, 1980-2000

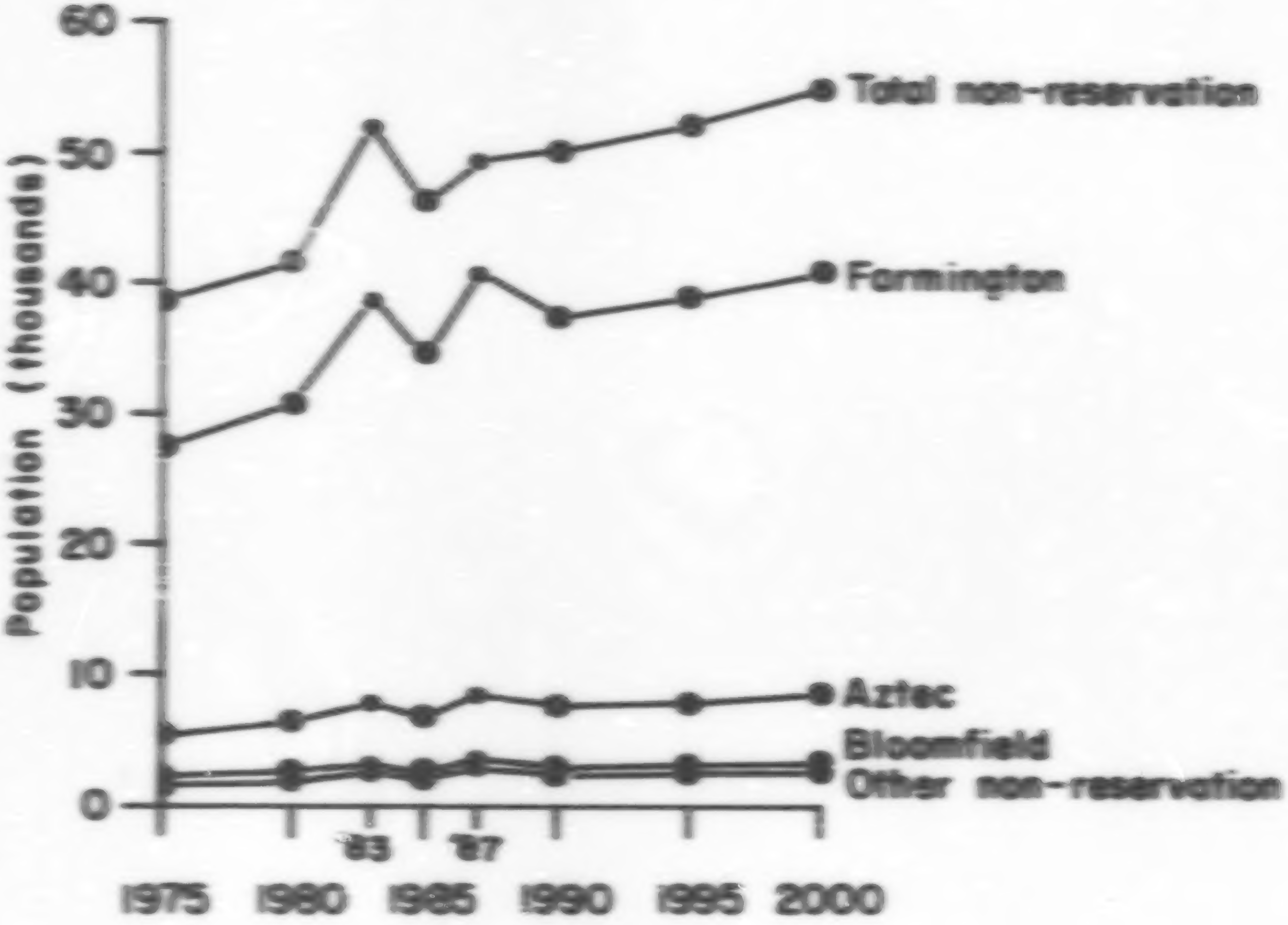

FIGURE 7-4: POPULATION ESTIMATES FOR NON-RESERVATION PORTION OF SAN JUAN COUNTY, 1980-2000

and by a new town to be built in the Burnham area by energy developers.[1] The populations for the new town in Table 7-25 are postulated as an example of the effect of the town. It would generally house less than 20 percent of the Navajo population in the county.

Because of the assumptions concerning Navajo employment and the likelihood that Navajo employees would come from elsewhere on the reservation, the Navajo population in San Juan County is expected to double by 1983 and to reach more than 70,000 by 2000. (For example, if family members of Navajos remain in Arizona, then the estimates in Table 7-25 are high.) Farmington will grow to 40,000 by 1987, but after a construction phase will not reach that size again until 2000. Overall, the county population will nearly double between 1975 and 2000 in the scenario.

The population of the county will increase about 16 percent by 1980 and 58 percent by 1990. The relative proportion of Navajos should increase from the present 40 to 60 percent. Some of the impetus for the increase in Navajo population will be the job opportunitites afforded by the Navajo Indian Irrigation Project (NIIP), as shown by Figure 7-5. Much of the increase is expected to occur in the vicinity of Shiprock, where housing with plumbing is being provided by the Navajo Tribe. The new town would be the largest urban area in the Navajo part of the county.

7.4.4 Housing and School Impacts

A. Housing

As shown in Table 7-26, the number of households in the county will probably double by 2000. Navajo housing demand will double by 1983 and will be three times the 1975 level by the late 1990's.

Much of the required new housing could be supplied by continued expansion of the Navajo Tribal housing development at Shiprock, which has already provided several hundred one- and

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[1] Morrison-Knudsen Company. *Navajo New Town Feasibility Overview.* Boise, Idaho: Morrison-Knudsen, 1975. Although the preliminary plans for the town suggest a fairly even Navajo-Anglo population, its location on the reservation and Farmington's proximity will probably eliminate its attraction to non-Indian families. WESCO's final environmental impact statement does not discuss a new town, stating that it is not a near-term possibility.

TABLE 7-26: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN SAN JUAN COUNTY, 1975-2000

Category	Year	Navajo Reservation Portion[a]	Non-Reservation Portion[b]	Total
Households	1975	5,000	11,000	16,000
	1980	6,600	12,400	19,000
	1983	10,200	15,600	25,800
	1985	8,600	13,800	22,400
	1987	13,800	16,300	30,000
	1990	15,000	12,700	27,700
	1995	13,900	15,600	29,500
	2000	17,700	16,300	34,000
Elementary Enrollment (20% of population)[c]	1975	5,000	7,300	12,300
	1980	6,600	8,300	14,900
	1983	10,200	10,400	20,600
	1985	8,600	9,200	17,800
	1987	11,000	10,800	21,800
	1990	10,100	10,000	20,100
	1995	11,100	10,300	21,500
	2000	14,200	10,900	25,100
Secondary (10% of population)[c]	1975	2,500	3,650	6,150
	1980	3,300	4,150	7,450
	1983	5,100	5,200	10,300
	1985	4,300	4,600	8,900
	1987	5,500	5,400	10,900
	1990	5,050	5,000	10,050
	1995	5,550	5,200	10,750
	2000	7,100	5,450	12,550

[a] Based on five persons per household through 1985 and four persons per household after.

[b] Based on 3.3 persons per household. Both this and the above assumption give high estimates during construction.

[c] Overall averages, which may be high during construction.

two-family homes with plumbing.[1] A shortfall in housing supply could result in a scattering of hogans, shanties, and mobile homes without running water in the vicinity of the irrigation and energy projects. If the new town is built, it could provide new employment opportunities and supply a significant proportion of the housing need for Navajo families. Water for the town could be drawn from the San Juan River along with water for the energy facilities. Finally, clusters of housing in the Farmington/Shiprock corridor are likely. Some Navajo homes in this area might be provided with running water by 1985.

By 2000, new off-reservation housing demands in Farmington, Aztec, and Bloomfield will be approximately 4,000, 800, and 300 homes respectively. With few vacancies in the housing market, many of these may be mobile homes near existing developments or along the highway east and west of Farmington.[2] The spread of mobile homes outside urban areas will be constrained primarily by the availability of water but also by the availability of other utilities and the location of privately owned land in the county.

B. Schools

As shown in Table 7-26, school enrollment can be expected to increase until 1990. These school enrollment changes also show distinctions between Indians and non-Indians. The Central Consolidated School District serving the reservation will be the most affected. The number of students will double by 1983 to 15,300 and then remain relatively constant until about 2000. Both elementary and secondary enrollment will not peak until 2000, and a low point appears about 1985.

At 30 students per classroom, about 260 classrooms will be needed in the Central School District by 1983 and another 200 by the year 2000. Financing for school construction on the reservation could be facilitated from the proposed energy projects if property taxes are levied, as they can be for this purpose.[3]

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[1] Running water is unavailable except in the northern section of the county. Even there, it was unavailable until Shiprock was hooked up with the Farmington municipal system. In the central and southern parts of the county, poor-quality groundwater is the only supply. See Section 7.3.

[2] U.S., Department of the Interior, Bureau of Reclamation, *El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement*. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, pp. 2-123 to 2-130.

[3] Property taxes generally do not exist in the Navajo Nation. However, a large portion of school costs are provided from the state level.

However, the revenues would lag behind the need by as much as 3 years. Some prepayment plan, or the proceeds from coal royalties, could provide the revenue for school construction with the necessary lead time.[1] New schools in the Burnham area, in particular, would help eliminate the present necessity for boarding schools.[2]

In the Farmington, Aztec, and Bloomfield School Districts, enrollment can be expected to increase somewhat during construction peaks.[3] The Farmington School District had excess classroom capacity in 1974[4] but will need about 145 classrooms by 1983. With expected enrollments, the need for additional classroom space will be minimal after the 1980's.

In higher education, the San Juan College campus of New Mexico University in Farmington (600-700 students) and the Shiprock Branch of Navajo Community College (more than 200 students) will perhaps triple their current enrollments. As employment opportunities become available to more Navajos, vocational training at the Shiprock Branch may increase even more. Training facilities, such as the Navajo Engineering and Construction Authority, train workers in heavy construction trades, and the demand for this training can be expected to increase as more energy development takes place on the reservation.[5]

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[1] Some of the financial requirement will also be borne by the Federal government, since currently about one-fourth of the Navajo children attend Bureau of Indian Affairs schools.

[2] U.S., Department of the Interior, Bureau of Reclamation, El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, pp. 2-121, 3-72 to 3-73.

[3] No large increases are expected because of the lowering birth rate of the white population. U.S., Department of Commerce, Bureau of the Census, "Projections of the Population of the United States, by Age and Sex: 1972 to 2000." Current Population Reports, Series P-25, No. 493 (1972).

[4] Real Estate Research Corporation. Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. IV-14.

[5] Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center Business Services, 1974, pp. 131, 148-49.

7.4.5 Land Use

Overall land use for energy development, primarily the strip mine operations, will be relatively small but will have local significance. Larger, long-term impacts will result from the NIIP.

The energy development analyzed here will use about 307 square miles.[1] About 5 percent of the land area of San Juan County will be removed from grazing. Much of this land is currently being used by Navajos as an extension of their reservation grazing lands. Another 10-15 square miles will be used for urban development and expansion. This development will occur mainly in the Shiprock/Farmington corridor of the San Juan Valley and in the Burnham area in connection with the new town.

Some of the changes are likely to affect the lifestyle of the Navajo. A reduction in grazing area may be beneficial for the long-term use of the land but may be troubling to families accustomed to a rural existence. The expansion of urban area and increased income will be of benefit only if adequate housing, water supply, and other infrastructure development allow the Navajo standard of living to improve. A number of existing roads will be improved and paved, but few new roads will be built. Expanding irrigation within the county will be the major land-related impact during the scenario time frame.

7.4.6 Economic and Fiscal Impacts

A. Economic

One immediate change from energy development will be in local income distribution. In San Juan County, positive benefits will accrue to the Navajo population as new employment opportunities allow them to increase their incomes and improve their living standards.

Currently, two of the greatest disparities between Indians and non-Indians occur in income and housing conditions.[2] The 1969 median income of white families in San Juan County was $9,343; the overall median in the county was $8,139. On the

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[1] See also U.S., Department of the Interior, Bureau of Reclamation. *Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement*, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, pp. 3-203 to 3-209.

[2] Detailed data are scarce. Hopefully, the field work mentioned earlier will provide a better basis for comparisons than do current data.

Navajo Reservation as a whole, a median per-capita income was $1,984;[1] comparable data on Navajo family income in the county are not available.

As shown in Table 7-27, the percentage of families with incomes in the $8,000-10,000 range increases through 1985 and then declines.[2] The median income and the proportion of households earning $15,000 and over fluctuates with the amount of construction activity (compare with Table 7-23). Overall, there will be relatively fewer low-income families, the result being a fairly constant median income. However, an overall increase in earnings for Navajos is expected, primarily because of a greater number of on-reservation job opportunities. The projected income distribution in Table 7-27 includes income increases for several hundred Navajo households currently in the area. Decreases in overall median income, when they occur, reflect a relative decrease in high-paying jobs in the oil and gas industries.

A second major economic effect will be the expansion of business activity, particularly on the Navajo reservation where a number of new business establishments should be located. The potential of a concentrated market in the new town near Burnham would be attractive to businesses, but several bottlenecks to business development might occur. A major problem will be financing new enterprises since credit, even from the Small Business Administration, appears to be difficult to obtain.[3] Also, since reservation land is communally owned and may not be sold, a use-right must be obtained from both the tribal government and the area agency of the Bureau of Indian Affairs before a business can be established. The application process involves some 20 steps and may take up to 5 years to complete.[4] This has discouraged business activity on the reservation, including those in the two largest expenditures categories for Navajos:

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[1] U.S., Department of Commerce, Bureau of the Census. Census of Population: 1970; Subject Reports: Final Report PC (2)-1F: American Indians. Washington, D.C.: Government Printing Office, 1973.

[2] The income estimates here do not take into account national trends in income growth from productivity gains and other causes.

[3] U.S., Commission on Civil Rights. The Navajo Nation: An American Colony. Washington, D.C.: Commission on Civil Rights, 1975, pp. 31-39.

[4] Ibid., pp. 39-40.

TABLE 7-37: PROJECTED INCOME DISTRIBUTION FOR SAN JUAN COUNTY, 1975-2000

	Annual Income (1975 Dollars)								
Year	Less than $4,000	$4,000 to $5,999	$6,000 to $7,999	$8,000 to $9,999	$10,000 to $11,999	$12,000 to $14,999	$15,000 to $24,999	$25,000 and over	Median Household Income
1975	.184	.068	.065	.075	.080	.125	.291	.113	12,706
1980	.138	.056	.052	.130	.078	.120	.311	.115	13,158
1985	.137	.060	.078	.144	.080	.118	.286	.098	12,800
1990	.126	.058	.072	.134	.084	.120	.308	.097	12,658
1995	.128	.056	.069	.128	.085	.120	.321	.101	13,058
2000	.119	.058	.069	.126	.088	.122	.323	.096	13,000

Source: Data for 1975 are adapted from U.S. Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities, and Counties: 1970. Washington, D.C.: U.S. Government Printing Office, 1973, by inflating to 1975 dollars. Income distributions for energy project construction and operation workers and service employees are from Mountain West Research Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, p. 58, assuming that "other newcomers" are operation employees and that new service workers earn between the U.S. average and the distribution for long-time residents. Northern Indian Irrigation Project workers are assumed to earn $7,800; see Morrison-Knudsen Company, Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. III-38.

automobile and truck sales and food purchases.[1] Most of the commercial benefits that will follow from an increase in the income of the San Juan County Navajos will go to businesses in Gallup and Farmington. It appears that business activity in these two communities will increase in any case and that activity at Shiprock and the new town site could be encouraged by an easing of credit and tribal policies on land aquisition.

Additional industries which may locate in the county include cattle processing facilities (feedlots and slaughter operations) of the Navajo Agricultural Products Industry, on-site facilities to process by-products of gasification,[2] and a possible rail spur north from Gallup to Burnham or Shiprock.[3] There is considerable uncertainty regarding the latter two.

The extent to which usual boom effects will occur in San Juan County is not known. Local inflation in housing costs and wage rates for service workers is taking place, but public services and facilities are in much better shape than in more isolated areas with no large towns. Price increases for retail goods and services will affect both Indians and non-Indians; the largest effect will be felt by those who do not benefit from wage inflation.

B. Fiscal

Public finance aspects are complicated by the location of facilities on an Indian reservation, as well as recent changes in federal mineral policies. The "dual entitlement" status of Indians means that the federal government provides many services (such as sanitation, health, and education), but local government must stand ready to provide services to Indians in their role as U.S. citizens.[4] The tribal council acts as another level of government in performing many traditional local government functions, such as police protection. Nevertheless, no public agency can levy property taxes within the reservation, except for a few limited items.[1]

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[1] Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. II-2.

[2] Ibid., pp. III-1 to III-2.

[3] Sickafoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, pp. 200-202.

[4] U.S., Commission on Civil Rights. The Navajo Nation: An American Colony. Washington, D.C.: Commission on Civil Rights, 1975.

The only substantial new revenue source available to the Tribal Council will be a royalty on coal. The amount of money involved is difficult to predict, because it depends on negotiation, but may be very substantial. Three estimates are presented here, based on three plausible assumptions. First, the current royalty rate of 17.5 cents per ton is maintained. With production growing to 42 million tons per year, annual revenues would correspondingly rise to $7.4 million. Second, negotiations for new leases could reflect the rise in coal values that has occurred since the old leases were signed. During the first 10 years of the old leases, New Mexico coal brought an average of $3.97 per ton,[2] so that the royalty represented 4.41 percent of mine-mouth value. Assuming the same percentage applied to prices expected as of the new mines' opening in 1980,[3] royalties of 39.7 cents would produce $16.7 million annually by 2000. Finally, royalties could follow principles laid down in the new Coal Mineral Leasing Act of 1976; namely, that a 12.5-percent rate will be attempted. That would generate $47.1 million annually for the Navajos by the end of the century.

For expenditures, the Tribal Council is assumed to provide all local government services for residents except education, health care, and construction of water and sewage facilities.[4]

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[1] As noted above, the Navajo Tax Commission is studying the potential for establishing property taxes. At rates comparable with Farmington's, some $57 million per year could be collected from the energy facilities in our scenario. See Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, p. 152.

[2] National Coal Association. Coal Facts 1974-1975. Washington, D.C.: National Coal Association, 1974, p. 68.

[3] $9.01, according to the SRI model. See Cazalet, Edward et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[4] In New Mexico, state and federal governments pay for most public school costs (79 percent in San Juan County), and more than one-fourth of the Navajo children attend federal (Bureau of Indian Affairs) schools. The Indian Health Service handles the other functions named above. See Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. III-16.

TABLE 7-28: FISCAL IMPACTS ON NAVAJO TRIBAL GOVERNMENT
(millions of 1975 dollars)

Year	New Capital Investment Each Year	Operating Costs Above 1975 Levels	New Coal Royalties[a]	Surplus (Deficit)
1976	1.13	.43	0	(1.56)
1977	.48	.62	0	(1.10)
1978	.45	.79	1.43	.19
1979	.62	1.03	1.43	(0.22)
1980	.68	1.29	2.86	.89
1981	.82	1.60	2.86	.44
1982	1.13	2.03	2.86	(0.30)
1983	.76	2.32	5.96	2.88
1984	.75	2.61	5.96	2.60
1985	.69	2.87	9.05	5.49
1990	.60	4.05	11.91	7.26
1995	.38	4.80	11.91	6.73
2000	.64	5.66	16.67	10.37

[a] If rate is 39.7 cents per ton.

The remaining functions should require $337 per capita for capital costs[1] and $129 per capita for annual operations.[2] Combining these data with the projected population increases, tribal finances would develop as shown in Table 7-28. The Tribe faces deficits at most times until 1983, when the second mine begins operations.[3] Thereafter, royalties are more than adequate, yielding surpluses of up to $10 million per year. (Financial alternatives are discussed below in the political impacts sections and in Chapter 14.)

Off the reservation, local governments will likely rely primarily on residential and commercial property taxes, sales tax, and utility fees to obtain revenue from the energy developments. San Juan County's 1973 tax rolls showed non-corporate

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[1] THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver: THK Associates, 1974, p. 30.

[2] U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Tables 429 and 432.

[3] Note that the population estimates include the irrigation project, but the revenue estimates do not.

TABLE 7-29: PROJECTED ADDITIONAL UTILITY FEES AND PROPERTY TAXES, ANGLO COMMUNITIES (millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Property tax, state	.12	.28	.47	.55	.72
Property tax, local	.46	1.10	1.85	2.17	2.85
Utility fees	1.13	2.72	4.55	5.36	7.03

valuations of $3,030 per capita (1975 prices).[1] Applying this factor to the prevailing Farmington mill levies[2] and adding the current average utility bill ($216 per capita per year),[3] potential municipal revenues are shown in Table 7-29.

Sales and income taxes depend primarily on the aggregate of new income. Based on the projected distributions of household income and current New Mexico tax rates,[4] an average of 4.4 percent of new personal income will be due the state in income tax. Assuming further, that five-eighths of personal income will be spent off the reservation, and that 56 percent of that will be on items subject to sales tax, income-related taxes can be summarized as in Table 7-30.

Finally, the state of New Mexico taxes coal mining and electrical production directly. "Privilege" and "severance" taxes total 1.25 percent of the gross value of the coal (less some minor deductions). Electricity generation is taxed at a

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[1] Bickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, p. 28.

[2] New Mexico, Department of Development, Economic Development Division, and University of New Mexico, Bureau of Business and Economic Research. Community Profile: Farmington, 1974-75. Santa Fe, N.M.: New Mexico, Department of Development, 1974.

[3] Real Estate Research Corporation. Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, Table 17.

[4] U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Table 435.

TABLE 7-30: PROJECTED ADDITIONAL INCOME AND SALES TAXES
(millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Personal income	51.8	107.3	165	197.6	235.8
Taxable sales	18.1	37.5	57.7	69.2	82.5
State share, sales tax (4%)	.72	1.5	2.31	2.77	3.3
Local share, sales tax (2%)	.36	.75	1.15	1.38	1.65
State income tax	2.28	4.76	7.18	8.75	10.48

rate of 0.4 mill per kilowatt-hour.[1] Based on scenario assumptions, these taxes should result in the revenues shown in Table 7-31.

The various revenues calculated above can be regrouped by level of government, as shown in Table 7-32, and then compared with new expenditures (Tables 7-28 and 7-33).

The simplest comparison to be made involves state government. A realistic assumption is that the state's costs will rise in proportion to population. These costs amounted to $621 per

TABLE 7-31: PROJECTED TAX REVENUES, PRIVILEGE AND SEVERANCE TAXES
(millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Coal	0.8	2.9	4.2	4.7	7.3
Electricity	0.0	7.8	7.8	7.8	7.8

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[1] The current law has been challenged as an unconstitutional interference with interstate commerce. See Bronder, Leonard D. Taxation of Coal Mining: Review with Recommendations. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976.

TABLE 7-32: PROJECTED TOTAL REVENUES FROM ALL SOURCES (millions of 1975 dollars)

Location	1980	1985	1990	1995	2000
Reservation	2.0	9.0	11.9	11.9	16.7
County, Municipal	2.0	4.6	7.6	8.9	11.5
State	3.6	17.2	22.0	24.6	29.6
Total: All state and local	8.6	30.8	41.4	45.4	57.8

capita in fiscal 1973.[1] Applying a scale-up for inflation and San Juan County population growth, the following cumulative cost increase is projected for the state: $12.6 million in 1980, $28.8 million in 1985, $43.3 million in 1990, $51.1 million in 1995, and $63.0 million in 2000.

These figures suggest that new state expenditures will be about twice as large as new revenues. However, not all of the

TABLE 7-33: SUMMARY OF ADDITIONAL LOCAL GOVERNMENTAL EXPENDITURES AND REVENUES, OFF-RESERVATION (millions of 1975 dollars)

Category	1980	1985	1990	1995	2000
Expenditure					
Capital[a]	12.4	17.3	20.1	8.8	18.2
Operating	.6	2.1	3.5	4.1	5.4
Annual expenditure if no borrowing	3.4	5.6	7.5	5.9	9
Annual expenditure, with borrowing[b]	2.1	4.9	8.2	9.6	12.6
Revenue	2	4.6	7.6	8.9	11.5

[a]Total for 5-year period ending at specified date.

[b]Current operating costs paid "as you go" plus all previous capital costs amortized over 20 years at 7 percent interest.

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[1] University of New Mexico, Bureau of Business and Economic Research. New Mexico Statistical Abstract, 1975. Albuquerque, N.M.: University of New Mexico, Bureau of Business and Economic Research, 1975, p. 61.

county's new people will come from out of state.[1] People who move about within the state will not cause any appreciable change in state government requirements. Although very difficult to forecast, at least half the new people should come from instate. If this is the case, the state government will experience very little net fiscal effect from these developments. However, the state, and its government, would grow in absolute size about 3 percent.

Using basic data from a recent western planning study,[2] capital costs for local government are estimated to be $2,360 per capita for county and municipal governments off the reservation; using New Mexico's average figures for local expenditures, these governments will also need $166 per person per year for operating costs. Combining these data with the projected population increases, additional local governmental expenditures are shown in Table 7-33. The previously tabulated revenue figures are included for comparison.

On a "pay as you go" basis of financing, local government faces a negative fiscal impact (new expenditures exceeding new revenues) until about 1990, after which the fiscal impact turns positive. In consideration of that long-term prospect, the municipalities may decide to borrow the portion for capital expenditures. After taking interest costs into account, that method is seen to result in slight but consistent deficits, growing to about $1.1 million per year by the end of the century.

Finally, the federal government is more involved fiscally in this scenario than in the others because of the large Indian population. Federal commitments undertake the expense and/or administration of sanitation, health, education and other functions. Moreover, the Department of Interior has a responsibility to oversee mineral lease terms and other major actions of the Tribal Council.

7.4.7 Social and Cultural Impacts

Changes in the Navajo culture and lifestyle may be considerable during the next 25 years because of increased agricultural activities as well as energy development. Navajos traditionally emphasize sharing and communal possession (as opposed to personal ownership of property) and harmony with nature and the land (as opposed to modern agricultural and industrial activities).[1] Development will result in challenges to these traditional attitudes and values, and conflicts will probably develop between the tribal government and locals.[2] The Burnham chapter's rejection of the proposed gasification-coal mining operations in the Burnham area is an example of this.[3]

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[1] This has been the case for workers on the San Juan Generating Plant project. See Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 8-17.

[2] THK Associates, Inc. *Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study*. Denver: THK Associates, 1974, p. 30.

Most Navajos seem to dislike urban living. For example, the growth of Shiprock as a relatively major settlement on the reservation occurred simultaneously with a large increase in drinking, automobile accidents, and child abuse.[4] Energy development is likely to bring even greater changes in family structures and daily schedules than urbanization. However, the availability of job opportunities on the reservation should be favored by most Navajos who prefer work locally rather than off the reservation.[5]

Some benefits from development are certain, such as increases in income and purchasing power and the consequent capabilities of Navajos to buy or build modern homes. However, the increase in the Navajo population in San Juan County is certain to take place more rapidly than the provision of such things as medical care, housing, and other social services. The current gap between medical needs and available care, already a major problem for the Navajos, will probably widen as population increases.

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[1] Some practices of the Navajos seem to contradict this description; for example, overgrazing is common.

[2] New Mexico State University, Department of Agricultural Economics and Agricultural Business. *Socio-Economic Impact on Rural Communities of Developing New Mexico's Coal Resources*. Las Cruces, N.M.: New Mexico State University, Department of Agricultural Economics and Agricultural Business, 1975, pp. 217-222; and Goodman, James M. "Some Observations on the Navajo Sense of Place." Unpublished paper, University of Oklahoma, Department of Geography, 1975; and Zickefoose, Paul W. *A Socio-economic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area*. Las Cruces, N.M.: New Mexico State University, Center for Business Services, 1974, pp. 39-45.

[3] *Ibid.*, pp. 435-436. This was not a consensus decision. However, it is indicative of a tribal split.

[4] Zickefoose. *Impact of Highway Construction in Shiprock Area*.

[5] Ruffing, Lorraine T. "Navajo Economic Development Subject to Cultural Constraints." *Economic Development and Cultural Change*, Vol. 24 (April 1976), pp. 611-21.

Roads, utilities, and retail establishment may also lag behind the population growth.

Quality-of-life effects on Farmington and the rest of the county are expected to be minor in comparison with those on the Navajo. During the oil and gas boom in the 1950's, Farmington's population grew more than 600 percent in 10 years. The expected rate of increase in coming years will be small by comparison. Although rapid growth has resulted in some service lags, notably in housing, Farmington's urban services and retail mix generally make it a better environment for its residents than smaller towns with the same problems but fewer amenities.

As for health services, the San Juan County Hospital is being expanded and remodeled to triple the 97-bed capacity (including specialized beds) of 1977. Consequently, health care should be less of a problem in the future. Among western cities, Farmington is well-equipped to handle the impacts of energy developments largely because of its size and infrastructure. Typical boomtown problems are not as likely to occur in Farmington, as they are in smaller, less developed localities.

Increases in both Indian and non-Indian populations within the county will increase contact between the two groups. Relations are likely to become strained, with increased conflict between Indians and non-Indians and between the Tribal Council and other governments.

7.4.8 Political and Governmental Impacts

As noted earlier, disagreements between the Navajo Tribal Council, local chapters, and individuals regarding the level of economic activity already exist. These are likely to continue, and perhaps even to intensify, as energy development becomes more extensive. For example, a confrontation over Navajo negotiation rights may occur, although the Navajos should be able to resolve their differences with the federal government more easily than some other tribes.

Navajos will receive increased revenues from industrial operations on their land, but the specific quantities and sources of those revenues depend on the tribe's priorities and the extent of the projects it pursues. Existing royalty rates are to be renegotiated by the Navajo Tax Commission because the tribe now believes that it did not receive fair treatment in the past. New contracts negotiated with prospective developers will provide more benefits to the tribes, not only in increased royalty rates but in such areas as training and jobs for Navajos.

In some ways the tribe's income needs are greater than those of many local governments. For example, road-building presents a particular problem because the Tribal Council is not recognized as a local government for various federal cost-sharing programs.[1] On the other hand, the federal government directly provides some services, such as health care.

Participation in tribal affairs and government by local Navajo chapters and individuals has increased with increased mining and industrial development on the reservation. Opposition to Anglo developments on Navajo land and the Tribal Council's nontraditional policies on such issues could have serious effects on Navajo community spirit in the San Juan County area. Contrasts between the poor, traditional Burnham area and more modernized Shiprock are great. However, residents of both areas have opposed non-Navajo exploitation of Navajo lands.[2]

The increasing importance of Farmington as the center of economic and other activities can be expected to continue. Most of the city's revenue comes from city-operated utilities, including electricity, water, and solid waste treatment operations. The city also benefits from growth outside boundaries because it provides water to Shiprock and a number of unincorporated towns in the Farmington/Shiprock corridor. Property taxes are its smallest source of revenue. The sales tax and utility revenues are likely to increase as the county's population increases. However, major capital improvements will be needed for adequate development of water and sewage systems. Police and fire protection also need to be improved.[3]

As noted in the population impact analysis, the demand for housing in San Juan County will probably double by 1985, with off-reservation needs greatest in Farmington and Aztec. Assistance for these and other communities, particularly during the short-term, will necessarily have to come from other levels of government. Pressure will likely be exerted on the state to provide ways of making more money available to traditional lending institutions for home mortgage loans. Although New Mexico presently does not have an administrative division of housing to administer fiscal programs to assist in the development of low or moderate income housing in rural areas, the state does provide limited aid through other state agencies.[1] Rapid energy development in the area may cause expansion of these administrative activities since eligibility for funds from the Federal government's "Community Development Block Grant Program" requires that a housing plan for assisting low- or moderate-income persons must be implemented by states requesting such assistance. The state also has a housing finance agency, the Mortgage Finance Agency, whose purpose is to assist in securing mortgage funds for traditional lending institutions.

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[1] U.S., Commission on Civil Rights. *The Navajo Nation: An American Colony*. Washington, D.C.: Commission on Civil Rights, 1975, p. 15.

[2] U.S., Department of the Interior, Bureau of Reclamation. *Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement*, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

[3] Real Estate Research Corporation. *Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. IV-4 to IV-13.

Due to the lack of a comprehensive countywide zoning plan, certain types of strip development in the San Juan Valley west of Farmington along U.S. 550 and on other limited private lands in the county are expected to continue.[2] Mobile homes, in particular, are likely to proliferate in the area, both on and off the reservation lands. Such development could result in undesirable impacts since the state does not now provide design criteria or standards for mobile home parks (except indirectly through health codes). Even if more effectively planned, the development of large parks for mobile homes (especially in remote areas) can lead to problems for local and county governments with regard to their ability to provide essential public services, regulate activities, control land use, and enforce regulations and standards.[3]

7.4.9 Summary of Social, Economic, and Political Impacts

The 1975 population of San Juan County will more than double because of the energy and agricultural development proposed in the Navajo/Farmington scenario. The largest increases are expected among the Navajo in the reservation portion of the county. The urban areas of the county (such as Farmington, Aztec, Shiprock, and a new town near Burnham) will attract much of the new population. Most of the secondary employment growth will be in Farmington, bringing its population to more than 40,000 by the year 2000. The largest increases in the demand for housing and schools will also be on the Navajo Reservation.

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[1] Rapp, Donald A. *Western Boomtowns*, Part I, Amended: *A Comparative Analysis of State Actions*, Special Report to the Governors. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976, pp. 20-22.

[2] U.S., Department of the Interior, Bureau of Reclamation. *Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement*, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, p. 3-84.

[3] The state recently reported problems of enforcement of solid waste rules and regulations, indicating this was primarily because small communities lacked the necessary capital for implementing required technologies and because of a significant lack of funds at the state level. Rapp. *Western Boomtowns*, page 28.

As employment opportunities and incomes improve, the lifestyle of many Navajos will generally change from a dispersed rural existence to a more settled and affluent one. The current rural distribution represents the highest rural population density in the nation. New provisions for modern housing with plumbing and kitchens will greatly affect the Navajo quality of life, and this is a major impetus for Navajo support of the concept of a new town in the Burnham area.[1]

Public services, especially health care, water, and sewers, will be among the greatest needs both on and off the reservation. Coordination between the tribe, local Anglo governments, and the federal government will become important within the county so that the quality of growth can be controlled. The tribe itself must derive virtually all its new revenues from coal royalties.[2] The above analysis has shown that a royalty rate of 40 cents per ton would ultimately provide net surpluses of more than $10 million per year. However, deficits may be experienced as late as 1982. Local Anglo governments similarly can expect surpluses eventually (late 1980's) but deficits in the short run.

In its analyses of the impacts reported in this section, the SAPP-Radian research team has had to rely on incomplete secondary data. As mentioned in the introduction to this section, field work currently under way is intended to provide better data and to fill in some of the gaps which currently exist. Further analyses of social, economic, and political impacts should provide more concise, in-depth results as data from this field work become available.

7.5 ECOLOGICAL IMPACTS

7.5.1 Introduction

The area considered for ecological impacts in the Navajo/Farmington scenario is bounded on the west by the Utah and Arizona borders and on the north by the San Juan National Forest. The study area extends eastward as far as the Chama River and southward to the Chaco Canyon.[1] Elevations range from 5,000 feet over much of the desert to 9,000 feet in the mountain areas.

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[1] Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975.

[2] Some net income should be derived from the irrigation project, but this cannot be estimated at present.

Energy development at Navajo/Farmington will take place in a desert environment. As noted earlier, the average annual rainfall is 6-8 inches in most of the area and up to 10 inches at higher elevations. Limited precipitation, coupled with excessive grazing, are the major factors controlling the composition and productivity of the terrestrial ecosystem.

7.5.2 Existing Biological Conditions

The coal fields being developed at Navajo/Farmington lie in a broad expanse of desert. Table 7-34 summarizes plant and animals characteristic of the biological communities found in the scenario area. Vegetation south of the San Juan River is very sparse desert grass and shrubland, with species composition reflecting the slight saltiness of much of the soil. Indian and non-Indian ranchers are a major influence on this ecosystem. For example, livestock grazing on the Navajo Reservation has removed most of the plant cover, and much of the topsoil has been carried away by erosion.

The scarcity of water in the area also limits animal population. The fauna is typified by a variety of desert-adapted rodents, lizards, and songbirds.[2] Several birds of prey are found in the area. Foxes, coyotes, and badgers constitute the bulk of the mammalian predators. Except for small numbers of antelope using the more productive grass and shrublands northeast of Farmington, there are few game animals in the area. Rare or endangered species include the peregrine falcon, bald eagle, and black-footed ferret.

The desert is bounded on the north by irrigated croplands, natural marshlands, and riparian woods found in the San Juan River floodplain. In addition to a relatively diverse and abundant assemblage of mammals and reptiles, this zone of well-watered vegetation supports a wide variety of birds, both

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[1] This area includes most of the present and potential influences of human populations living in the Farmington area and encompasses the ranges of migratory game animals.

[2] The San Juan Valley lies in the Central Flyway and provides habitat for winter migratory waterfowl and spring breeding populations.

TABLE 7-36: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, NAVAJO/FARMINGTON SCENARIO

Community Type	Characteristic Plants	Characteristic Animals
Desert Grassland-Shrub	Blue grama Galleta grass Indian ricegrass Alkali sacaton Russian thistle Shadscale Mormon tea	Ord's kangaroo rat Silky pocket mouse Spotted ground squirrel Whitetailed prairie dog Collared lizard Horned lark Coyote Antelope
Pinyon-Juniper Woodland	Pinyon pine Utah juniper Curl-leaf mountain mahogany Cliff rose Gambel oak	Barbary sheep Mule deer Cliff chipmunk Pinyon mouse Gambel's quail Pinyon jay
Riparian	Indian rice grass Rabbitbrush Tamarisk Willows Cottonwood Elm	House mouse Western harvest mouse Porcupine Desert cottontail Red fox Great blue heron Mule deer
Mid-elevation Conifer Forests	Ponderosa pine Blue spruce Douglas fir Aspen Mountain maple Alder Oceanspray Gambel oak	Mule deer Elk Turkey Chickadee Cooper's hawk Band-tailed pigeon Pigmy nuthatch
Subalpine Conifer Forests	Corkbark fir Subalpine fir Engelmann spruce Aspen Mountain maple Box myrtle Snowberry	Mule deer Elk Mountain goat Bighorn sheep Beaver Marmot Marten Blue grouse Gray jay

resident and migratory. For example, the waterfowl habitat of the San Juan Valley is of regional significance.[1]

The foothills to the north and east are pinyon-juniper woodland with some scrub oak and a variety of grasses and forbs. Greater rainfall in these areas makes the foothills more productive than the desert grass and shrublands. Consequently, the fauna is more diverse and abundant there, especially the bird life, which finds a broad spectrum of food and habitats within this type of vegetation. These foothills are also important areas for deer, especially in winter.

Above the pinyon-juniper zone and more distant from Farmington lie coniferous forests consisting primarily of ponderosa pine and Douglas fir. This vegetation supports a diverse fauna distinct from that of the pinyon-juniper zone. For example, beaver inhabit most of the mountain streams, and bald eagles winter in this area. Game animals include turkey, as well as deer and elk during the winter.

The highest forest type is dominated by corkbark fir and Engelmann spruce. Alpine meadows occur above the timberline. Big game animals use these high forests and meadows as summer range.

The quality of the aquatic habitat in the San Juan River is influenced by the Navajo Reservoir, constructed in 1962, which is located about 45 miles upstream from Farmington. Cold water discharged from the lower layers of the reservoir controls stream conditions 15-18 miles below the dam.[2] Beyond this distance the river assumes a more typical desert character, becoming warmer and silty. The colder waters support a trout fishery, and a limited warm-water fishery is located near Farmington. Below Farmington, many non-game fishes occur; however, the water is too turbid for game fishes. Other streams in the area are primarily intermittent and while they support short-lived invertebrate and plant populations, they probably do not contain fish.

The mineral cycles of arid desert land in San Juan County are "slowed down" relative to many temperate grasslands and

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[1] U.S., Department of the Interior, Southwest Energy Federal Task Force. Southwest Energy Study, Appendix H: Report of the Biota Work Group. Springfield, Va.: National Technical Information Service, 1972. PB-232 104, p. 26-30.

[2] U.S., Department of the Interior, Bureau of Reclamation. El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, p. 2-84.

forests. Nutrients such as nitrogen and phosphorus are
confined to the upper soil layers, due to limited leaching, and
this may separate them from the plant roots.[1] Also microbial
decomposition of litter and wood is limited to the short periods
of adequate soil moisture following rainstorms.[2] However, the
principal factor limiting vegetative production is usually mois-
ture rather than nutrients.[3]

7.5.3 Major Factors Producing Impacts

The air, water, population, and social impacts described
earlier affect the ecological changes that may occur. The lar-
gest non-energy development affecting the ecosystem is the
Navajo Indian Irrigation Project (NIIP), which began operation in
1976.[4] Following this initial phase, the NIIP will add about

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[1] Working in the Curlew Valley in northern Utah, Jurinak,
J.J., and R.A. Griffin. *Factors Affecting the Movement and*
Distribution of Anions in Desert Soils, US/IBP Desert Biome
Research Memo 72-38. 1972, found the majority of available
phosphorus in the upper 15 centimeters (cm) of soil and Skujins,
J. *Nitrogen Dynamics in Desert Soils: I, Nitrification*, US/IBP
Desert Biome Research Memo 72-40. 1972, "demonstrated that only
the top three cm layers of these soils take a significantly
active part in nitrogen turnover", with "occasionally significant
activity" found in the 15 to 20 cm layer.

[2] Tiedemann, A.R., and J.O. Klemmedson. "Nutrient Availa-
bility in Desert Grassland Soils Under Mesquite (*Prosopis*
juliflora) Trees and Adjacent Open Areas." *Soil Science Society*
of America Proceedings, Vol. 37 (January-February 1973), pp.
107-11 found nitrogen largely limiting production when adequate
water was supplied to desert grassland species, along with sulfur
and phosphorus to some extent.

[3] The production of the vegetation is low. The gross pri-
mary productivity of the several vegetation types found in the
area is estimated to be about 1.7x10^6 kilocalories per hectare
per year, which is almost an order to magnitude less than pro-
ductivity at the other scenario locations (except for Kaiparo-
wits) of this study. Productivity is chiefly limited by rain-
fall, and coverage values for the sparse vegetation range from
about 5 to 20 percent.

[4] The system will consist of a main open canal and three
laterals, with water delivered to the fields by sprinkler sys-
tems. Possible crops are corn and sugar beets, and several crops
a year are feasible. The Animas-LaPlata Project, a Bureau of
Reclamation program of reservoirs and irrigated agriculture in
two river valleys, is roughly one-seventh the size of the Navajo
Indian Irrigation Project and will use Animas River water, which
will be returned to the San Juan through the LaPlata River.

10,000 acres to the system each year until it reaches its planned limit of 96,630 acres in 1986. During the 1975-1980 period, the projected energy development includes construction of a 250 million standard cubic feet per day (MMscfd) mine-mouth Lurgi gasification plant and its associated access road, pipeline connection, and water line. Ancillary facilities, including improvements to existing roads and highways on and near the Navajo Reservation, will also be developed. Table 7-35 shows habitat losses over the entire study period. As indicated in the previous section, this development will increase the population of the non-reservation portion of San Juan County by 4,600 and the reservation population by 7,900.

The remaining energy facilities of the Navajo/Farmington scenario will be constructed during the 1980-1990 period. These include a 3,000 megawatt-electric mine-mouth power plant in 1985 and a 250-MMscfd Synthane plant in 1990. In addition to the coal mines to supply these plants, ancillary facilities to be built during this period include water and gas lines and a single right-of-way for the extra-high voltage transmission lines. A network of hard-surfaced roads surrounding the energy complex and irrigation lands should also be completed.

TABLE 7-35: DESERT LAND CONSUMPTION, NAVAJO/FARMINGTON SCENARIO (acres)

Period	Facilities Siting	NIIP	Mining
1975-1980	1,560	4,000	
1980-1990	4,570	192,630	
1990-2000	2,300		
Post-2000			55,200
Cumulative Total	8,430	196,630	55,200
Grand Total	260,260		

NIIP = Navajo Indian Irrigation Project.

Impacts during the 1990-2000 decade accrue from the continued expansion of the three surface mines and operation of the gasification plants and power plant. A Synthoil liquefaction plant is to be constructed and on-line by 2000, including a surface coal mine as well as water and syncrude pipelines. This decade will see the population stabilize at a new level reflecting the activities of the four energy-related facilities. Population in the year 2000 is expected to have grown to 125,400 from its original 1975 level, with 70,900 living on the reservation and 54,500 living off it as described in Section 7.4.

7.5.4 Impacts

A. Impacts to 1980

Most of the early impacts of the scenario will be a consequence of construction activities. At the same time, expansion of the NIIP will begin modifying the ecological baseline.

About 1,560 acres of desert vegetation will be permanently lost to facility and access road construction by 1990. These lands are currently used for grazing, primarily by sheep. An average of 365 acres of forage is required to produce one cow with calf or five sheep per year.[1] Because actual Navajo stocking rates are often three times the recommended rate, the forage required to produce up to 12 cows with calves or 60 sheep per year may be lost.

Impacts on wildlife at the Lurgi construction site itself will be comparatively minor. The larger, more mobile animals, such as badgers and horned larks, will be driven away by the activity. Many of the smaller species with restricted movement patterns, such as the pocket mouse or kangaroo rat, will be killed directly. For the most part, the species affected are widespread throughout the entire desert, and the habitat affected by construction activity is neither unique nor distinctive. The cliffs along the Chaco River, however, constitute important nesting habitat for the area's birds of prey, particularly the golden eagle and redtail hawk. The water line feeding the Lurgi plant will be constructed along the rim of the Chaco wash, causing birds of prey to abandon their nests if the disturbance coincides with the nesting period. Once the water line is in place, some of the birds could be expected to return, but original nesting density would probably not be restored.

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[1] U.S., Department of the Interior, Bureau of Reclamation, Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 3 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, page 2-131.

An increase in poaching of game animals and shooting of nongame species has been observed widely throughout the western states during periods of construction and mineral exploration. Poaching in northern New Mexico is already extensive, in some places equalling legal kill levels, according to a recent study in the Guadalupe Mountains by the New Mexico Department of Game and Fish.[1] Antelope and deer are the species most likely to suffer from extensive poaching. The nesting birds of prey in the Chaco wash are especially vulnerable to shooting as a consequence of waterline construction.

B. Impacts to 1990

During the second scenario decade, the construction-related effects experienced before 1980 will be intensified. In addition, the secondary impacts of increased population will become more pervasive and significant.

Agricultural impacts in this decade are primarily losses of grazing lands. About 4,570 acres of desert grassland are destroyed by facilities construction. The forage production lost as a result could sustain as many as 40 cows with calves or 200 sheep per year. Cumulative change of land use to irrigated agriculture by the NIIP will total 196,630 acres when the project is completed in 1986. Assuming that all of this area is no longer grazed, up to 1,620 cows with calves or 8,080 sheep would not be produced. By comparison, the number of cows and calves in San Juan county in 1974 totaled 23,805 while sheep totaled 42,692.[2]

Actual habitat disruption by construction is, as indicated above, of minimal ecological significance within the area being studied. However, the additional increase in game poaching and illegal shooting of nongame could cause noticeable declines in wildlife populations by 1990.[1] The most vulnerable big game populations are the deer (Deer Management Area 10) and the antelope located in the foothills southeast of Farmington. The declining deer populations are nonmigratory and their range is particularly accessible by vehicle on oil and gas exploration trails. The antelope herd is already declining due to harrassment and illegal harvest, and could be virtually eliminated by 1990.

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[1] Poaching differs from legal hunting in its impact on game populations by being indiscriminate with respect to age, sex, and season. By removing pregnant females and nonbreeding young, it can exert a significant impact on the ability of the population to maintain an adequate base of breeding adults. Poaching not only harms game populations directly, it reduces the number of surplus animals which may be legally taken. Without license revenues, management and patrol programs designed to protect the herds are difficult to finance. The New Mexico Department of Game and Fish therefore views poaching as one of their most significant problems.

[2] U.S., Department of Commerce, Bureau of the Census, 1974 Census of Agriculture; Preliminary Report, San Juan County, New Mexico. Washington, D.C.: Government Printing Office, 1976.

The impact of the scenario in increased demand for backcountry types of recreation will begin to be felt by 1990. Initially, much of this demand will focus on the San Juan Mountains, particularly the newly designated San Juan Wilderness area and the adjacent Rio Grande Wilderness. The San Juan Forest staff has indicated that use permits may be used to limit access in 4-5 years. With demand for recreational areas, adjacent foothills and mid-elevation forests will be used to a greater degree.[2] Vegetation along stream banks, lakes, and in meadows at high altitudes may deteriorate due to the effects of camping, horses, and foot traffic.[3] Other impacts might include: the disturbance and subsequent redistribution of elk, especially on calving grounds; fragmentation of key deer ranges by recreational development on private lands;[1] harrassment of deer and other wildlife by heavy off-road vehicle (ORV) use in the hills east of Farmington, especially in winter;[2] and local erosion.

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[1] Poaching would normally be associated with peak construction employment. In this scenario, however, laborers who migrate to the area to work on one project may remain there awaiting the beginning of the next. Many of these people may be unemployed at least part of the time between projects and may poach game for meat.

[2] These areas are scenically attractive, dotted with Indian ruins, and often easily accessible on old trails remaining from the era of gas and oil exploration. Foothill lands controlled by the Ute Mountain and Southern Ute Reservations are, however, essentially closed to dispersed recreation by tribal attitude and policy. Most of the recreational pressure from the Farmington area is likely to concentrate in the foothills of the San Juan National Forest in Colorado and in the highlands east of Farmington, including the Carson National Forest.

[3] The San Juan National Forest presently has rules restricting camping within a specified distance of certain high-altitude lakes and streams. High meadows are summer range for both deer and elk, and support distinctive populations of small vertebrates and insects of both scientific and aesthetic interest. Delicate alpine flora can be greatly reduced in diversity or destroyed after a few years of trampling.

Expanding urban development will also begin to produce noticeable impacts by 1990. Strip development along the San Juan River will fragment riparian habitat. While some species of ducks, shorebirds, and songbirds will lose some habitat due to this development, the loss will be compensated for, in part, by the NIIP. Species such as the great blue heron, which depend heavily on fish and other aquatic fauna, may decline. Feral[3] dogs, already a problem, will increase in numbers and disturb deer wintering in the uplands adjacent to the San Juan River or in the valley itself. Finally, heavy ORV use within roughly 20 miles of concentrations of human populations will deteriorate some terrain. Even without development of a new town at Burnham, some clustering of dwellings in the area may be expected because of its location relative to the NIIP and the energy developments.

Difficulties in procuring funds for adequately updating municipal sewage facilities may result in the direct discharge of most of the treated sewage generated by the growing urban populations during this decade. Especially during late-summer periods of low flow, the added nutrients and biochemical oxygen demand carried in sewage treatment effluent, coupled with agricultural runoff, could cause serious problems of algal growth and lowered dissolved oxygen from Farmington to below Shiprock. If treatment facilities are improved during the second half of the decade these effects will diminish.

The demand for legitimate hunting, especially for big game, will also increase as construction-related populations grow. Hunting pressure on deer is already high especially in the foothills near Farmington.[1] Anticipated increases in hunting combined with present declines in the deer population from poor reproduction will reduce the success of hunting.

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[1] This could be particularly significant west of Durango, parallel to U.S. 160 from Durango to Cortez, and in the Animas River valley below the Purgatory ski area. However, Colorado's land-use laws provide for county approval of such development, which may afford a measure of control.

[2] Assuming a total of 28,000 new families by 1990 and one off-road vehicle for each four families, yields an estimate of 7,000 such vehicles. By 2000, the total is 8,750. These could exert very significant impacts on nearby foothill habitats if uncontrolled.

[3] Feral dogs are defined as domesticated canines which have returned to a wild state or animals produced in the wild by parents that were once domesticated.

Game animals on Navajo lands are subject to shooting that is controlled more by Indian social custom than by state laws and management. Game populations suffer from year-round or uncontrolled harvest, as well as from habitat destruction by heavy grazing from domestic animals. Changes in wildlife use on reservation lands from new Indian towns or changed population distributions are not expected.

The expansion of irrigated agriculture during this period will begin to establish a trend toward replacement of the desert fauna with species typical of agricultural areas. The limiting factors will become the availability of food and cover. Waterfowl may benefit from the habitat provided by surface canals adjacent to croplands, especially where grains are grown. Desert rodent species may be replaced by those commonly associated with croplands and which consequently have a higher probability of contact with man. Plague is endemic in northwest New Mexico, and as human and rodent populations grow, the probability of cases of human plague may increase.

C. Impacts to 2000

During this decade, mines will continue to expand, affecting the largest area as described in Section 7.7.5. The Synthoil liquefaction plant site and oil line will remove 2,300 acres of desert vegetation. The forage produced on this acreage would support as many as 20 cows with calves or 100 sheep per year, assuming that the entire area is currently grazed. The major cumulative habitat losses of the Navajo scenario will take place in an area of desert bounded by the San Juan River, New Mexico Highway 44, and the Chaco Wash.

By the year 2000, the withdrawal of water from the San Juan Basin will have risen by 236,000 acre-feet per year (acre-ft/yr) for the NIIP, 67,640 to 78,960 acre-ft/yr for the new energy facilities, and about 15,350 acre-ft/yr for the increased population. Most of this water will be diverted directly from the Navajo Reservoir.[2] The net effect may be to decrease flows of cold water downstream. Although the storage project maintains a minimum flow of 400 cubic feet per second (cfs) for downstream use, lowering of potential flows closer to this minimum will have few beneficial, and many adverse, consequences, including: limiting the already excellent cold water fishery for rainbow and brown trout below Navajo Reservoir; some deposition of silt and sand bars downstream which will reduce the stability of bottom habitats, including fish spawning and nesting sites; warming of waters and reduction of total amount of aquatic habitat in areas of depleted flow (effects of flow reduction will be much more significant than increase in dissolved solids; and reduction in marsh vegetation within the floodplain, reducing waterfowl nesting habitat.

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[1] Between 1970 and 1973, hunters using Deer Management Area 10 (which includes almost all the New Mexico deer habitat in this scenario) increased from 8,159 to 12,600. Concurrently, hunter success dropped from 24.9 percent to 11.4 percent.

[2] Personal Communication, Staff of Bureau of Reclamation, Farmington Office, January 1977.

Wastewaters impounded at the four plant sites could attract desert animals and waterfowl. The impact of these wastewaters on wildlife is dependent on accessibility and their composition. The wastes of the coal conversion plants are of particular interest because they may contain various organic compounds known or suspected to be carcinogenic (see Section 12.6). Evaporation ponds are likely to contain high concentrations of chemicals and be unpalatable and odoriferous. In addition, sublethal or chronic effects would probably not affect a sufficient number of animals to be significant on a regional scale.

As reported previously in the air impact analysis, ground level sulfur dioxide (SO_2) and, nitrogen oxide concentrations from the proposed facilities will generally be at least an order of magnitude below the federal standards even under the worst conditions. The highest 3-hour average is calculated as 459 micrograms per liter ($\mu g/m^3$)(0.18 parts per million), about one-third the secondary ambient standard. Further, these concentrations over most croplands will be much lower, on the order of 10 $\mu g/m^3$ or less. At this level, SO_2 has not been found to produce either acute or chronic damage to the type of crops to be grown in the irrigation project. The effects of air-dispersed trace elements, including large amounts of fluorine, cadmium, arsenic, and mercury, cannot be predicted. However, under similar circumstances, concentrations of these elements (with the exception of fluorine) were not predicted to reach toxic concentrations in terrestrial environments.[1] Fluorine concentrations, with all facilities on-line, may approach cumulative damage levels in sensitive plants of 1 part per billion over extended periods of time, depending on stack gas scrubbing method.[2]

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[1] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. III-60-64.

[2] BLM. FEIS: Kaiparowits, p. III-65.

Local changes in the mineral cycles at Farmington are likely to occur in two major categories: physical changes in nutrient pools, and changes in the biological sector of the nutrient cycles. Physical changes will be due primarily to erosion (particularly from the wind) of surface soil and litter. These impacts will arise from construction, livestock overgrazing, and recreational activities, especially ORV use and surface mining. Another physical change will be the minimization of stream flow variations as a result of operational practices of the Navajo Reservoir. This will reduce the deposition of soil in riparian habitats which now occurs following high-flow periods.

The impact of biological changes in the mineral cycles through vegetation loss will be limited spatially because the desert is divided into "microwatersheds" with an individual shrub at the center of each small catchment area.[1] Changes from energy development will operate on the level of the individual microwatersheds rather than on some larger unit such as a stream watershed or plant community.

Other potential impacts on the biological portion of mineral cycling arise from SO_2 emissions. A considerable amount of sulfur will be emitted into the air and may eventually be deposited on land. The impact of this additional sulfur is not known, but it may be expected to accumulate in the ecosystem, eventually reacting with biological components and beginning to cycle within the systems.[2] However, given the anticipated level of scenario development, it is unlikely that sufficient sulfate will enter the soil to induce an overall acidification problem, especially since many soils are slightly alkaline.

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[1] See, for example, Stark, N. *Distillation--Condensation of Water and Nutrient Movement in a Desert Ecosystem*, US/IBP Desert Biome Research Memo 73-44 1973; Charley, J.L. "The Role of Shrubs in Nutrient Cycling," in McKell, C.M., J.P. Blaisdell, and J.R. Goodin, eds. *Wildland Shrubs--Their Biology and Utilization*, USDA Forest Service General Technical Report INT-1, Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1972; Garcia-Moya, E., and C.M. McKell. "Contribution of Shrubs to the Nitrogen Economy of a Desert-Wash Plant Community," *Ecology*, Vol. 51 (Winter 1970), pp. 81-87.

[2] See Tiedemann, A.R., and J.O. Klemmedson. "Nutrient Availability in Desert Grassland Soils Under Mesquite (*Prosopis juliflora*) Trees and Adjacent Open Areas," *Soil Science Society of America Proceedings*, Vol. 37 (January-February 1973), pp. 107-11; and Tucker, T.C., and R.L. Westerman. *Gaseous Losses of Nitrogen from Soil of Semi-Arid Regions*. US/IBP Desert Biome Research Memo 73-37. 1973.

The Navajo Reservoir is currently drawn down about 45 feet per year. By the year 2000, it will be drawn down 95 feet per year to supply 226,000 acre-ft/yr for the NIIP, 67,040-78,960 acre-ft/yr for the new energy facilities, and 15,350 acre-ft/yr for the increased population. Energy facilities will withdraw water between Farmington and Shiprock.

The impacts of these water withdrawals on the reservoir will be minor. Game fish populations now in the reservoir are expected to continue to reproduce, although shallow water habitat important to spawning and juvenile survival will be seasonally reduced as the lake level drops. Algae and aquatic macrophytes, if fluctuating lake levels allow their growth, will be stranded along the shoreline as the water recedes. After they have decayed and the lake level again rises, a decrease in dissolved oxygen could occur in areas where vegetative growth is permitted.

About 209 cfs will be annually returned to the San Juan River above Shiprock at Chaco Wash from seasonal irrigation runoff and artificial aquifers created by the NIIP. This return will contain high total dissolved solids concentrations and quantities of pesticides and fertilizers. Though base flows at Navajo Dam should maintain flow at Shiprock, the dilution of this irrigation return could become critical to water quality at and below Shiprock during periods of low flow.[1] The ability of the river to dilute the concentrated irrigation runoff could be enhanced by almost 20 percent through the use of once-through cooling processes at the energy facilities.[2]

D. Impacts After 2000

A total of 55,200 acres will be disturbed by surface mining. Environmental factors which will limit the reestablishment of vegetation are: limited rainfall and high evaporation, erodibility and salinity of much of the overburden material, general absence of good topsoil, and uncontrolled grazing by large livestock populations on the Navajo Reservation.

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[1] Low flow of record at Shiprock since the construction of Navajo Dam is 68 cubic feet per second.

[2] About 75 percent of the total water required for energy production is lost to evaporation in forced-draft cooling towers. If once-through cooling is employed, this water can be returned to the San Juan above Chaco Wash and Shiprock. The increased dilution of 20 percent reflects changes in volume and disregards losses from the river due to evaporation or seepage; it similarly does not reflect periods of increased rainfall or other seasonal variation.

Overgrazing by Navajo livestock is a critical factor. Reseeding efforts at Black Mesa and on the Navajo Reservation have failed several times, largely because livestock destroyed the early growth.[1] Alternative techniques, such as planting seedlings, may substantially increase the success of revegetation, but at present no formal plans have been developed to initiate a seedling program. Current practices at two surface mines in the four corners area involve application of up to 12 inches of water for a period of 2 years in an effort to re-establish growth of both native and non-native species. Invasion of non-palatable species (Russian thistle) has occurred, and some species common to wetter locations have been established, but successful long-term maintainance of these species does not appear likely. Data for a period of longer than two years are not available. The overall effect of surface mining will be extensive removal of desert habitat from existing vegetation and use patterns. The full impact of these changes will not occur until after 2000.

The forage produced in a year on the acres lost to mining would support as many as 150 cows and their calves or 760 sheep, if the Bureau of Indian Affairs recommended stocking rates are used. If this range is stocked at current rates, the forage produced would support up to 450 cows and their calves or 2,270 sheep.

Attempts by ranchers to compensate for these forage losses by moving sheep or cows to other, unmined lands will probably be unsuccessful. Overgrazing on Navajo lands is already heavy, and increased grazing pressure on remaining rangelands may decrease forage production to the point where livestock carrying capacities are significantly lower than they were prior to energy development.

Table 7-36 illustrates the impact of cumulative grazing losses through the lifetime of the scenario's industrial facilities, excluding losses to urbanization and roads. The present 64:36 ratio of sheep to cattle reported for San Juan County was used to estimate a realistic combined total of sheep and cattle

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[1] Thames, J.L., and T.R. Verma. "Coal Mine Reclamation in the Black Mesa and the Four Corners Areas of Northeastern Arizona," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America.* Grand Forks, N.D.: University of North Dakota Press, 1975.

TABLE 7-36: POTENTIAL LIVESTOCK PRODUCTION FOREGONE: NAVAJO/FARMINGTON SCENARIO[a]

Acres Lost		Animal Equivalents			
		SCS Recommended Stocking		Maximum Actual Stocking (1975)	
		Cows/Calves	Sheep	Cows/Calves	Sheep
1975-1980	1,560	3	6	3	28
1980-1990	4,570	9	17	23	51
1990-2017	2,310	5	8	15	24
Post-2017[b]	55,200	112	200	336	602
Cumulative Total	63,630	129	231	377	690
1974 Inventory[c] San Juan County		20,875	42,690		
Loss as % of 1974 Inventory		0.5%	0.5%	1.8%	1.6%
Loss to 2017[d]	236,630	471	712	4,383	2,126
Loss as % of 1974 Inventory		2.2	1.7%	5	5

[a] Includes transmission, pipeline, and water line rights-of-way.

[b] Assumes failure of reclamation efforts.

[c] U.S., Department of Commerce, Bureau of the Census. _1974 Census of Agriculture: Preliminary Report, San Juan County, New Mexico._ Washington, D.C.: Government Printing Office, 1976.

[d] Includes land "withdrawn for agricultural use".

production foregone.[1] This permits comparison with actual 1974 livestock inventories. All loss calculations are conservative because it has been assumed that all acres affected are grazed and that all have a relatively high grazing capacity for desert grasslands. As the table shows, neither sheep and cattle losses are potentially important, even if the present excessive stocking rate can be sustained over the time period of interest. Reduction in grazing area due to NIIP crop production are roughly triple those of the energy facilities.

7.5.5 Summary of Ecological Impacts

Most of the impacts associated with the Navajo scenario are continuous through time, rather than being localized within a specific period. Although they will begin with the first year of the scenario, noticeable regional effects will probably not become evident until after 1985. The most important of these impacts--judged on the basis of geographic extent, potential for altering the size and/or stability of populations of important species, or likelihood of resulting in a change in the structure or function of a large portion of an ecosystem--are summarized below. Their expected cumulative impact on selected animals is presented in Table 7-37.

Major ecological impacts are ranked into classes in Table 7-38. These classes are based on the extent of habitat and number of species affected by a given action.

Class A impacts such as habitat removal or fragmentation, the replacement of the desert ecosystem by cultivated croplands, and little or no revegetation on mined areas, affect several species over a wide area and are considered the most severe. Class B impacts locally affect fewer species and include illegal shooting and poaching as well as the potential loss of small herds of antelope. Impacts that are likely to affect the fewest animals and are extremely localized (such as the consumption of impounded wastewaters) are ranked as Class C.

Assuming that climatic factors, poor soils, and overgrazing will combine to preclude effective reclamation of strip mines, the combined effect of habitat loss from energy developments will be to cause an overall decline in the water- or food-limited desert fauna and to replace it by a cover-limited fauna typical of farmlands. Total animal abundance will probably increase due to the impact of the irrigation project, in spite of the opposite trend associated with energy development.

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[1] U.S., Department of Commerce, Bureau of the Census. *1974 Census of Agriculture; Preliminary Report, San Juan County, New Mexico*. Washington, D.C.: Government Printing Office, 1976.

TABLE 7-37: FORECAST OF STATUS OF SELECTED SPECIES

	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7-37: (Continued)

	[illegible]	[illegible]	[illegible]
[illegible] [illegible]	Little change.	Possible loss of [illegible] birds in the [illegible] Valley north of [illegible].	Decline in numbers of wintering birds.
[illegible]	Little change.	If present, likely to extirpated.	
[illegible]	Little change.	If present below [illegible], likely to decline markedly or become extinct.	
[illegible]	Little change.	If present, likely to be reduced to extirpation.	
[illegible]	Decline.	Probable loss of nesting birds in coal area.	
[illegible]	Little change.	Decline of nesting populations.	Continued decline, becoming locally infrequent.
[illegible]	Slight decline.	Strong decline and possible local extirpation.	
[illegible]	Slight decline.	Strong decline.	Probable equilibrium at low numbers.
[illegible]	Little change.	If present above [illegible], likely to decline markedly or become extinct.	
[illegible] [illegible] [illegible]	Stable or slight decline.	Moderate decline in number.	Continued decline in number.
[illegible]	Stable.	Moderate decline in nesting; wintering populations decline slightly.	Continued low nesting populations, and slight to moderate decline in wintering population.
[illegible]	Moderate increase in population.	Continued increase, stabilized after [illegible].	Stable overall trend.
[illegible]	Moderate decline in numbers.	Accelerated decline especially of breeding regions.	Continued decline at lowered rate.

TABLE 7-38: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

Impact Category	1975-80	1980-90	1990-2000+
Class A	Direct habitat removal Habitat fragmentation by NIIP & development Shift in ecosystem: desert < cultivated cropland	Direct habitat removal Habitat fragmentation by NIIP & development Shift in ecosystem: desert < cultivated cropland Grazing losses (NIIP) Loss of endangered species	Direct habitat removal Unsuccessful revegetation of mine sites Grazing losses (NIIP and Mines) Loss of endangered species
Class B	Poaching of Big Game Shooting of non-game species	Lowered flows in San Juan Illegal shooting and poaching Loss of Antelope Increase in recreation demands; ORV's Feral Dogs	Lowered flows in San Juan Intensified overgrazing by Navajo on remaining rangelands Increase in recreation demands; ORV's Feral Dogs
Class C		Consumption of impounded wastewater by wildlife Increased incidence of plague	Consumption of impounded wastewater by wildlife Increased incidence of plague
Uncertain	Introduction of pesticides, fertilizers	Introduction of pesticides, fertilizers	Introduction of pesticides, fertilizers

NIIP = Northern Indian Irrigation Project
ORV = off-road vehicle

Two groups of species will serve as barometers or indicators of this change. Species adapted to the desert (which are expected to decline because of habitat loss) include Gunnison's prairie dog, Ord's kangaroo rat, the silky pocket mouse, and white-throated wood rat. Decline in these, particularly the prairie dog, will affect other species adapted to living among and praying on them. For example, the western burrowing owl, ferruginous hawk, and badger may be expected to exhibit sharp declines. In addition to a decrease in predators, fragmentation of open areas will contribute to the decline of gray and kit foxes. The NIIP will provide a food base for increased numbers of other rodents and birds, some of which may become pests (such as the pocket gopher, which may increase where root crops [such as sugar beets] are grown). Gophers, mice, and voles are now found in the area and are expected to become common as the expansion of agriculture proceeds. Some of these rodent populations could become reservoirs for plague. Swallows and various small farmland sparrows will also increase; although the horned lark will still be a common resident, it will no longer be the dominant species.

Coincident with this increase in smaller wildlife, there will probably be an expansion of the population of several predators or omnivores adapted to farmland situations. Many of the hawks already breeding in the area could increase in numbers as a result of the increased prey base in the irrigated lands, provided that adequate nesting sites are present. These include the marsh hawk, kestrel, redtail and roughleg. Red fox and striped skunk will probably also increase.

Toxic substances discharged into on-site holding ponds cannot be ruled out as hazards to some wildlife, but the possibility of their constituting a threat on a regionwide scale appears to be small. The ecological impact of pesticide and fertilizer use by the NIIP cannot be predicted.

Withdrawals from the San Juan River for irrigation and energy use will reduce flow to minimum requirements during dry periods. This reduction will lower both abundance and diversity in the aquatic ecosystem. Floodplain marshes, important to waterfowl may be reduced in extent.

The most widespread of the scenario's impacts, with the greatest potential for reducing the abundance and diversity of native plant and animal life, are those arising from the growth of San Juan County's population from 61,700 to 125,400 over the study period. These impacts include fragmentation of riparian and foothill habitat by residential and commercial development, which will place additional stress on deer, waterfowl, and other water-related avifauna. In particular, antelope near Farmington are expected to be lost or decline to a few individuals. Vandalism will tend to reduce diversity and abundance of birds of prey near town and within the area of the energy developments. In addition, domestic and feral dogs may become a significant stress on both small and large animals adjacent to the San Juan Valley. A major impact of increased population will be to increase erosion losses and thus reduce vegetative cover.

Several endangered species may be affected by energy development. The black-footed ferret is known to exist near the scenario area but not within it. If present, they will probably be eliminated. Three of seven active peregrine falcon nests in the Rockies are located near Durango close to an area receiving increasing use by campers and recreationists. The reason for their continued decline is uncertain; if they are disturbed by hikers, they may desert these nesting sites. At least one bald eagle nest is known in the San Juan Valley above the Navajo Reservoir; heavier recreational use of this area could result in its abandonment. The Colorado squawfish and the humpback sucker (recently removed from "threatened" status) have been reported from the San Juan River. If present below Shiprock, they could be eliminated locally by flow depletion.

Several of the significant impacts described above can be affected by changes in technologies. If mined areas are planted with native seedlings following a complete replacement of top soils, reclamation will have a better chance to succeed, although long-term stability is still an issue. In addition, salt deposition from cooling tower drift would be eliminated by the use of a cooling lake (although such a lake would almost be as large as the area affected by cooling tower drift), by the use of dry cooling towers, or by once-through cooling processes. A decrease in water consumption would benefit the riparian habitats along the San Juan River. In addition, controls over access to remote habitats, especially by vehicle, would minimize the adverse effects to the ecosystem from the enlarged population of 125,400. However, such restrictions on use would substantially reduce the aesthetic and recreational values of the ecosystem.

Analysis of these impacts has been hampered by lack of adequate data, inherent variability in ecological structure and function, and the limited predictive theory relating change to potential future effects. Significant limitations exist in defining the long-term pattern of success with recreation in these desert environments and in predicting the effect on vegetation and animals from chronic exposure to low levels of criteria pollutants and trace elements. Some of these problems are the focus of current research at the Environmental Monitoring and Support Laboratory at Las Vegas and multiagency monitoring programs on land reclamation and water quality.

7.6 OVERALL SUMMARY OF IMPACTS AT NAVAJO/FARMINGTON

Major benefits resulting from the hypothetical developments in the Navajo/Farmington scenario are the production of 500 million cubic feet of gas and 100,000 barrels of oil daily and 3,000 megawatts of electric power. These benefits will accrue primarily to people outside the area, but locally substantial increases in per-capita income, trade, and other economic development will take place principally to the Navajo Nation.

These economic changes and the social and political impacts originate primarily from the population increase of 125,400 by 2000. However, supplying adequate housing, sanitation, water, and other services will be a major problem. Although major economic benefits will accrue to the region, median income of the reservation will be only slightly affected. Benefits to the

Navajo Nation depend on employment patterns, taxation, and royalties. Off-the-reservation towns will have limited funds to supply the services demanded of them.

The magnitude of these impacts are highly dependent on where and when development takes place. If facilities were located off the reservation, the benefits would largely affect non-Indians, and adequate financing could be provided for non-Indian towns. If facilities were developed at a slower pace or with fewer gaps between construction activities, fewer oscillations and requirements for rapid growth in schools and government services would be required.

Due to meteorological conditions, the plumes from the facilities are rarely expected to interact and thus create significant violations of ambient air quality standards.[1] Individually, only the Synthoil plant greatly exceeds standards due to the low-level fugitive hydrocarbon (HC) emissions. In selected instances, the facilities exceed both Class I and Class II significant deterioration increments. The ambient air quality standards are currently exceeded for both particulates and HC at Farmington, and the new population and facilities can be expected to exacerbate this problem. In addition, the plumes of the plants will be visible from any part of the area and will typically reduce visibility about 10 percent, with much greater reduction under adverse meteorological conditions.

Technological variables affecting impacts include improved emission controls or reduced plant size. Both these alternatives, if carried out at an adequate operational level, would reduce the number of potential standards violations. In addition, coal beneficiation steps that would remove inorganic sulfur would also reduce conflicts with sulfur standards.

The potential new water consumption of 102,700 acre-feet per year within the New Mexico portion of the San Juan Basin meets or exceeds that allotted to New Mexico. Conflicts over use are likely to increase, both between users in the basin and those presently using downstream flow. This use would significantly affect the quality of the surface water (especially in such characteristics as total dissolved solids, temperature, and the ability of the water to transport sediment) and other features of stream hydrology. Groundwater quality could also be affected by leaching chemicals from the settling ponds, and erosion of the pond dikes could affect surface waters.

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[1] Exceptions may occur during downslope wind conditions. New Mexico Environmental Improvement Agency Staff, Personal Communication, November 23, 1976.

Dry or wet/dry cooling significantly decreases water consumption but would both increase costs and decrease plant efficiency. Among other changes, this would result in some expansion of mining, air emissions, and a slightly larger population. Changes in cooling methods could affect up to 13 percent of available water in the Basin. Other technological changes could be significant, including the use of treated sewage for plant cooling (as is done in some southwest areas). The use of combinations of cooling towers and evaporation ponds could also reduce some water use, especially during the winter.

Several significant ecological effects are likely to occur from the combined impacts of surface mining, land use, new population, and the use of water. Water withdrawal from the San Juan will adversely affect the aquatic and riparian ecosystems. Due to the poor soils and limited water, successful reclamation will be difficult. Over the life span of the plants, this is likely to affect approximately 55,000 acres of land. The new population will also fragment habitat, damage vegetation, and contribute to the erosion of soils, as well as stressing wildlife populations through intentional or inadvertent harrassment. Thus, certain species are likely to be eliminated or significantly reduced on a local basis. The combined impact of mining and desert irrigation will favor an animal community in the desert portion of the scenario area which is more typical of farmlands or grasslands than of the original arid desert shrub ecosystem. The effect of toxic air and water emissions from energy facilities is difficult to predict, but there is no evidence at present that their effects will be significant.

Several of these impacts could be significantly affected by reclamation technologies or by extensive social controls. By using seedling transplants, adequate water and fertilization, reclamation might have a better short-term chance of success. However, the costs of this practice would be significant and would divert water from other beneficial uses. Controls over human use of the area would minimize attrition of habitat but would require an extensive use of permits for recreational use and zoning. Provisions for habitat control in the river valley and habitat management programs on farmlands can also affect vegetation and animal abundance. These policies are also discussed in Chapters 13 and 14.

CHAPTER 8

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENTS AT THE RIFLE AREA

8.1 INTRODUCTION

The Rifle scenario is located in Rio Blanco and Garfield Counties in northwestern Colorado (Figure 8-1).[1] As shown in Figure 8-2, the hypothetical developments include crude oil and coal and oil shale mining, conversion, and transportation. Two TOSCO II (the Oil Shale Corporation) oil shale retorting facilities of 50,000-bbl/day (barrels per day) and 100,000-bbl/day capacity are supplied by underground mines; pipelines transport the upgraded oil to refineries outside the region. A 3.4 million tons per year room-and-pillar coal mine supplies a 1,000-MWe (megawatts-electric) power plant that provides electricity to local users and the regional power grid via 500-kV (kilovolt) transmission lines. The 400-well oil field produces 50,000 bbl/day, which is transported via pipeline to refineries outside the region. The construction schedule and selected technical details of these facilities are presented in Table 8-1.

Landownership in the area is predominantly federal, with state and private ownership clustered along streams in valleys. The area population has been increasing in the last decade, but unemployment is low. Employment is highest in service industries, but retail trade, construction, and agriculture are also major employers. The area enjoys some tourist trade as it is on the most commonly used route to Aspen and Vail. The quality of life

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[1] While this hypothetical development may be similar to some developments proposed by Moon Lake Electric Company, Midland Coal Company, Blue Mountain Coal, Gulf Oil, Shell Oil, Superior Oil, American Fuels, Colony Development, Union Oil, Occidental Oil Shale, Paraho Oil Shale Demonstration, Consolidation Coal, W.R. Grace and Hanna Mining, Utah International, and others, it must be stressed that the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions. TOSCO II appeared to be a good choice when an oil shale technology was being selected at the beginning of the project. It now appears that modified *in situ* is more likely to be used and a modified *in situ* development will be added to this scenario in the final impact analysis report.

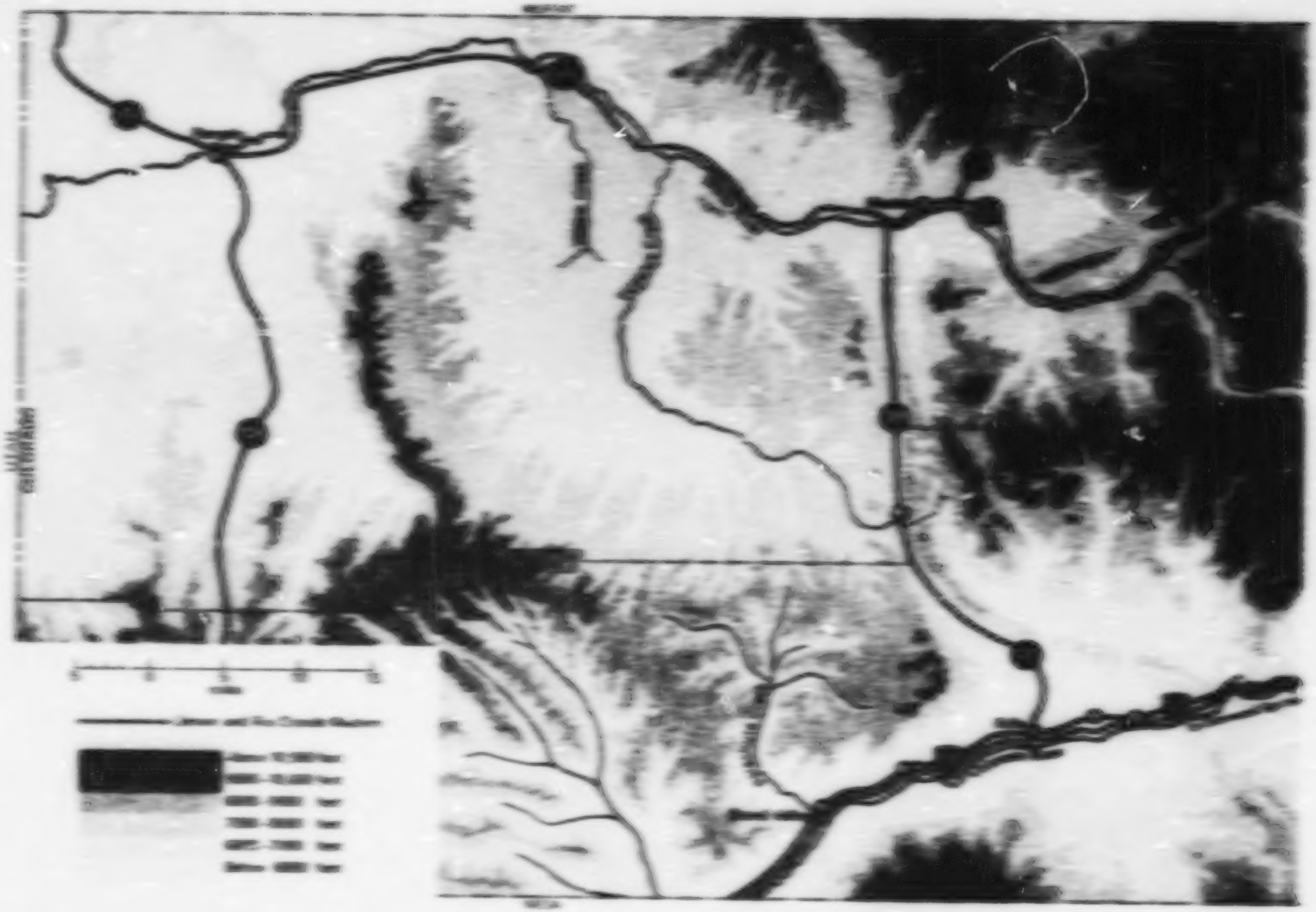

FIGURE 8-1: LOCATION OF THE RIFLE SCENARIO AREA

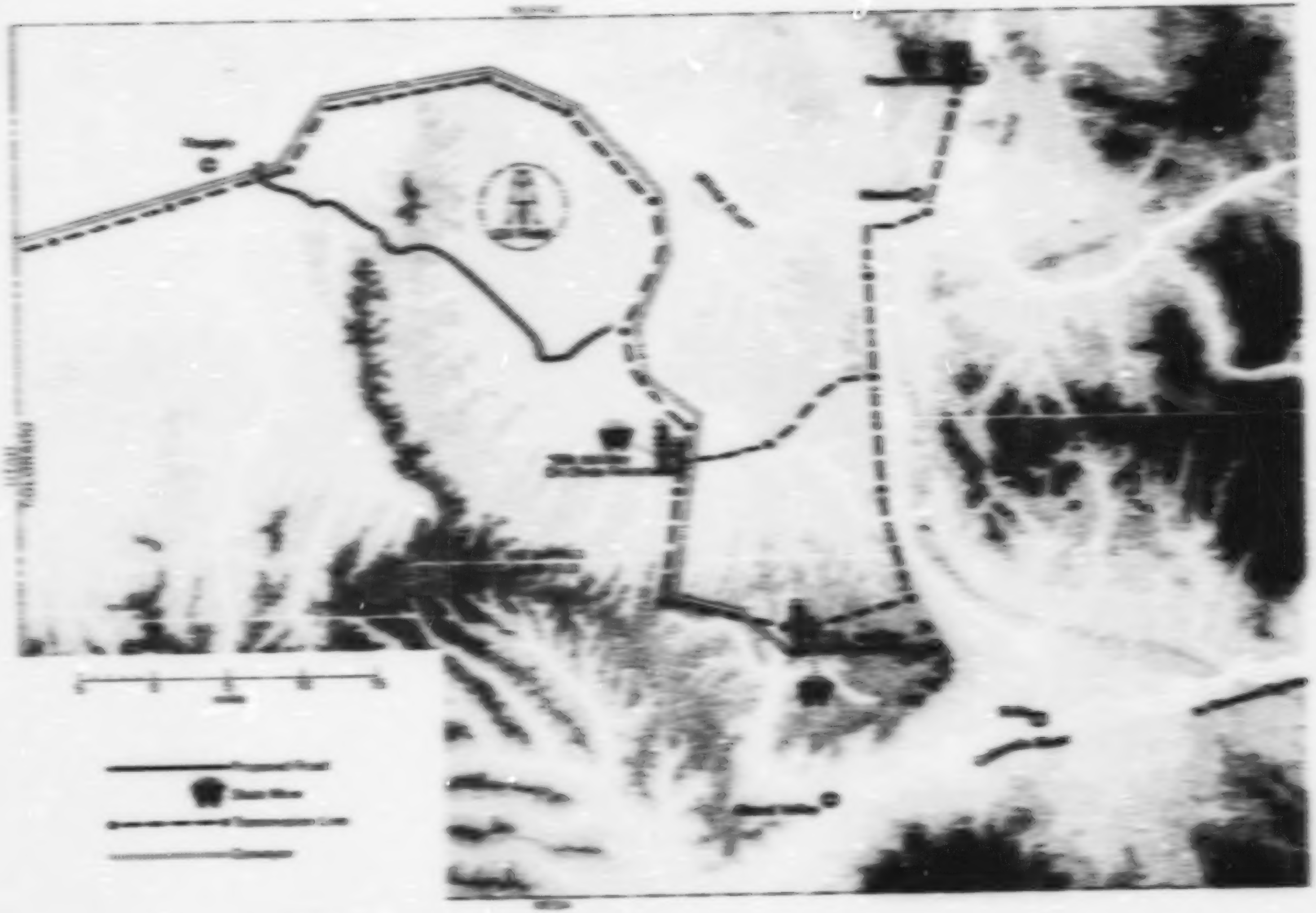

FIGURE 8-2: ENERGY FACILITIES IN THE RIF/2 SCENARIO

TABLE 8-1: RESOURCES AND HYPOTHESIZED FACILITIES AT RIFLE

[illegible]		Characteristics	
Coal[a] (billions of tons)		Coal	
Resources	8	Heat Content[b]	11,[illegible] Btu's/lb
Proved Reserves	4	Moisture	11 %
Oil Shale[c] (billions of barrels)		Volatile Matter	[illegible] %
Resources	117	Fixed Carbon	[illegible] %
Proved Reserves	58	Ash	5 %
Oil (billions of barrels)		Sulfur	0.6 %
Resources[d]	10		

Technologies	Facility Size	Completion Date	Facility Serviced
Resource Production			
Coal			
One underground room-and-pillar mine utilizing continuous miners	1.5 MMtpy	1980	Power plant
Oil Shale			
Two underground room-and-pillar mines	26 MMtpy 51 MMtpy	1985 1990	Oil shale retort Oil shale retort
Oil			
600 wells drilled at the rate of 100 per year	12,500 bbl/day 12,500 bbl/day 12,500 bbl/day 12,500 bbl/day	1982 1983 1984 1985	Pipeline Pipeline Pipeline Pipeline
Conversion			
1,000-MWe power plant consisting of two 500-MWe turbine generators; 35% plant efficiency; 80% efficient limestone scrubbers, 99% efficient electrostatic precipitator, and wet forced-draft cooling towers[e]	500 MWe 500 MWe	1979 1980	
One 50,000 bbl/day and one 100,000 bbl/day TOSCO II oil shale facilities with wet forced-draft cooling towers	50,000 bbl/day 100,000 bbl/day	1985 1990	
Transportation			
Coal			
Two conveyor belts from the mine to the plant		1980	Power plant
Oil			
One 16-inch pipeline	50,000 bbl/day	1982	Oil well field
Oil Shale			
Three conveyor belts	26 MMtpy 51 MMtpy	1985 1990	Oil shale retort Oil shale retort
Shale Oil			
One 20-inch pipeline	150,000 bbl/day	1985	Oil shale retort
Electricity			
One line (to regional power grid)	500 kV	1980	Power plant
One line (to local power grid)	345 kV	1980	Power plant

bbl/day = barrels per day
Btu's/lb = British thermal units per pound
kV = kilovolts
kw = kilowatts
MMtpy = million tons per year
MWe = megawatts-electric

[a] 1976 Keystone Coal Industry Manual. New York, N.Y.: McGraw-Hill, 1976, p. 577. Proved reserves are calculated as 50 percent of the defined resources.

[b] [illegible], F.E., [illegible] Busch, and [illegible]. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience. [illegible] Contract No. 68-02-1307. Dayton, Ohio: Monsanto Research Corporation, 1975.

[c] National Petroleum Council, Committee on U.S. Energy Outlook. U.S. Energy Outlook. Washington, D.C.: National Petroleum Council, 1972, pp. [illegible]. Proved reserves are calculated as 50 percent of the defined resources.

[d] National Petroleum Council, Committee on U.S. Energy Outlook, Oil and Gas Subcommittee, Oil and Gas Supply Task Group. U.S. Energy Outlook: Oil and Gas Availability. Washington, D.C.: National Petroleum Council, 1973.

[e] Due to format restrictions, this facility was defined as four 250-MWe units for the calculations of the social/economic impacts.

in the area is considered excellent by the residents, and a larger than normal fraction of the population is of retirement age.

The terrain is rugged to mountainous, and climate varies with altitude. Annual precipitation is between 12 and 20 inches, and annual snowfall is between 60 and 100 inches. The climate is cool, with only 50 to 120 frost-free days per year. Due to the absence of pollution sources, air quality is good, although air stagnation occurs in the valleys.

Biological communities in the Rifle area also vary with altitude. Valley floors near streambeds are primarily croplands but contain alder, oak, and willow trees, and a large variety of birds and small mammals. As the elevation increases, plant and animal species become more characteristic of mountain areas, moving from pinyon-juniper to fir and pine at high altitudes with deer and elk, as well as some black bear. Hunting for deer and elk is a major activity in the area.

The White and Colorado Rivers and their tributaries are the principal surface water sources for the area, with numerous intermittent streams flowing into them. Water quality in the smaller streams is generally poor, primarily as a result of irrigation runoff. However, water quality is good in the major streams. Groundwater is located predominantly in alluvial aquifers which are associated with the surface streams. Groundwater is also found in a bedrock aquifer associated with the Mahogany Zone, the richest source of oil shale. Additional site characteristics are shown in Table 8-2 and elaborated in greater detail as needed in the following sections.

8.2 AIR IMPACTS

8.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Rifle area is currently affected by a number of air emission sources, the most significant of which is the Mid-Continent Coal and Coke Company. Measurements of concentrations of criteria pollutants[1] taken through late 1975 in the Rifle area indicate that no federal or Colorado ambient air standards are violated. Based on these measurements, annual average background levels for all six criteria pollutants have been estimated in micrograms per cubic meter ($\mu g/m^3$) as :

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[1] Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, non-methane hydrocarbons, nitrogen dioxide, oxidants, particulates, and sulfur dioxide. The term "hydrocarbons" is generally used to refer to non-methane HC.

TABLE 8-2: SELECTED CHARACTERISTICS OF THE RIFLE AREA

Environment	
Elevation	4,700-11,000 feet
Precipitation	12-20 inches annually
Temperature	January mean daily minimum = 7.7°F July mean daily maximum = 89.4°F
Air Stability	Inversions more frequent in fall and winter months. Inversions and air stagnation common in valleys year-round. Dispersion conditions better on plateaus.
Vegetation	Elder, oak, and willow near valley floors. Juniper, fir, and pine at higher elevations.
Social and Economic[a]	
Land Ownership	
Federal	70 %
State and Private	30 %
Population Density	4.1 per square mile
Income[b]	$4,000 per-capita annual

[a] Figures given are the Rio Blanco/Garfield County average.

[b] U.S., Department of Commerce, Bureau of Economic Analysis, "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

particulates, 12; sulfur dioxide (SO_2), 2; nitrogen dioxide (NO_2), 5; hydrocarbons (HC), 130; carbon monoxide (CO), 1,000; and oxidants, 68.[1]

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[1] These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are now assumed to be relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

B. Meteorological Conditions

The worst dispersion conditions for the Rifle area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), unchanging wind direction, and relatively low mixing depths.[1] These conditions are likely to increase concentrations of pollutants from both ground-level and elevated sources.[2] Since worst-case conditions differ at each site (largely due to the wide variety of terrain in the Rifle area), predicted annual average pollutant levels will vary among sites even if pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion about 31 percent of the time. Hence, plume impaction[3] and limited mixing of plumes caused by temperature inversions at the plume height can be expected to occur regularly.[4] Good dispersion conditions associated with moderate winds and large mixing depths are expected to occur about 16 percent of the time.

As is the case at most western sites, the potential for dispersion of pollutants in the Rifle area varies considerably by season and time of day. Fall and winter mornings are most frequently associated with poor dispersion, due largely to more persistent high-pressure areas with lower wind speeds and mixing depths.

8.2.2 Emission Sources

The primary emission sources in the Rifle scenario are a power plant, two oil shale facilities, supporting mines, and population increases. Pollution from energy-related population increases was estimated from available data on average emissions per person in several western cities.[5] Most mine-related pollution originates from diesel engine combustion products, primarily nitrogen oxides (NO_x), HC and particulates. Although the mines are underground and dust suppression techniques are hypothesized in the scenario, some additional particulates will come from blasting, coal piles, oil shale crushing, and blowing dust.[1]

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[1] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[2] Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emissions.

[3] Plume impaction occurs when stack plumes run into elevated terrain because of limited atmospheric mixing and stable air conditions.

[4] National Climatic Center. *Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities*. Ashville, N.C.: National Climatic Center, 1975.

[5] Refer to the introduction to Part II for identification of these cities and references to methods used to model urban meteorological conditions. This scenario models only concentrations for Rifle and Grand Valley, Colorado.

The hypothetical power plant in this scenario has two 500-MWe (megawatts-electric) boilers, each with its own stack.[2] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2 and 40 percent of the NO_x.[3] One 75,000-barrel storage tank at the plant, with standard floating roof construction, will emit up to 0.7 pound of HC per hour.

The power plant and the two oil shale conversion facilities are cooled by wet forced-draft cooling towers. Each cell in the tower circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist.[3] The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,300 pounds per year for each cell.[4]

Table B-3 displays emissions of five criteria pollutants for each of the three facilities. In each case, most emissions come from the plants rather than the mines. The largest single contributor to total emissions is the 100,000-bbl/day (barrels/day) TOSCO II plant for pollutants except CO and NO_x, in which case the power plant emits higher levels. The 50,000-bbl/day TOSCO II plant, while contributing only half as much pollution as the larger TOSCO plant, produces more SO_2 and far more HC than does the power plant.

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[1] The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency is investigating this question and will be used to inform further impact analysis.

[2] Stacks are 500 feet high, have an exit diameter of 23.6 feet, mass flow rates of 1.57×10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

[3] Efficiencies are Radian's estimates of current industrial practices.

[4] The power plant has 22 cells, the 100,000-barrels per day (bbl/day) TOSCO II oil shale plant has 10, and the 50,000-bbl/day TOSCO II oil shale plant has 5.

TABLE 8-3: EMISSIONS FROM FACILITIES
(pounds per hour)

Facilities[a]	Particulates	SO_2	NO_x	HC	CO
Electrical Generation (500-MWe)	185	972	2,387	68	222
TOSCO II Plant (100,000-bbl/day)	262	3,079	1,138	1,431	101
TOSCO II Plant (50,000-bbl/day)	131	1,540	569	715	50

bbl/day = barrels per day
CO = carbon monoxide
HC = hydrocarbons
MWe = megawatts-electric
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

[a] Emissions from these facilities are almost entirely from the plants because each plant's associated mine is hypothesized to be underground. The power plant is equipped with two 500-MWe boilers. A detailed description of each facility is contained in the Energy Resource Development Systems description to be published as a separate report in 1977.

8.2.3 Impacts

A. Impacts to 1980

1. Pollution from Facilities

Construction of the hypothetical power plant begins in 1977 and the plant becomes operational in 1980. Few air quality impacts are associated with the construction phase of this plant or with those coming on-line by 1990, although construction processes may increase wind-blown dust, which currently causes periodic violations of the federal and state 24-hour ambient particulate standards.

Table 8-4 summarizes the concentrations of four pollutants predicted to be produced by the power plant. These pollutants (particulates, SO_2, NO_2, and HC) are regulated by federal and Colorado state ambient air quality standards, which are also shown in Table 8-4. This information shows that the typical concentrations associated with the plant, when added to existing background levels, are below federal and state standards. However, the peak concentrations produced by the plant do violate federal 3-hour HC standards and Colorado's 24-hour SO_2 standard.

TABLE 8-4: POLLUTION CONCENTRATIONS FROM A 1,000 MEGAWATT POWER PLANT (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]				Standards[b]				
			Peak		Health			Non-significant Deterioration	
	Background	Typical	Plant	Complex	Primary	Secondary	Colorado	Class I	Class II
Particulates									
Annual	30		.4		75	60	45	5	10
24-hour		.2	10	.9	260	150	150	10	30
SO_2									
Annual	2		2.3	0.1	80			2	15
24-hour		1.3	225	4.6	365		15	5	100
3-hour		7	550	25		1,300		25	700
NO_2[c]									
Annual	5		3.7	.2	100	100			
HC[d]									
3-hour	20	.4	10	1.2	160	160			

HC = hydrocarbons NO_2 = nitrogen dioxide SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical 1,000-megawatt-electric-power plant. Annual average background levels are considered to be the best estimate of short-term background levels.

[b] "Primary and secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant exhaust is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

Table 8-4 also lists Non-Significant Deterioration (NSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] Class I standards, intended to protect the cleanest areas such as national parks, are the most restrictive.[2] Peak concentrations from the power plant exceed Class II increments for 24-hour SO_2 and Class I increments for 24-hour particulates, annual SO_2, and 3-hour SO_2.

Since the plant exceeds Class I increments, it would have to be located far enough from any Class I areas to allow emissions to be diluted by atmospheric mixing prior to reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations would require a minimum buffer zone of 13.6 miles between the hypothesized power plant and any Class I areas boundary.[3] Although proposed Class I areas are within 15 miles of the plant site, the White River National Forest is less than 10 miles to the east. If this forest was designated a Class I area, the power plant would violate allowable increments (Figure 8-3).

2. Pollution from Towns

Several small towns, such as Rifle and Grand Valley, are expected to increase their populations as a result of the energy development in this scenario. By 1980, the population of Rifle should increase from 2,500 to 2,950, and Grand Valley should

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[1] Non-Significant Deterioration standards apply only to particulates and sulfur dioxide.

[2] The Environmental Protection Agency initially designated all Non-Significant Deterioration areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class II. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

[3] Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area windroses which show wind direction patterns and strengths for various areas and seasons. Hence, the direction of Non-Significant Deterioration areas from energy facilities will be critical to the size of the buffer zone required.

FIGURE 8-3: AIR IMPACTS OF ENERGY FACILITIES IN THE RIFLE SCENARIO

grow from 360 to 730.[1] These increases will contribute to increases in pollution concentrations due solely to urban sources. Table 8-5 shows predicted concentrations of five criteria pollutants for Rifle in 1980. Concentrations are estimated at a point in the center of the town and at a point 3 miles from the center.

When concentrations from urban sources are added to background levels, the federal HC standard is exceeded.[2] No other federal or state standards are approached by the combination of background and urban sources by 1980.

B. Impacts to 1990

1. Pollution from Facilities

Two new facilities are hypothesized to be constructed by 1990 in the Rifle area. A 50,000-bbl/day TOSCO II oil shale plant will become operational in 1985, and a 100,000-bbl/day plant will become operational in 1990. No additional facilities are planned after 1990. Tables 8-6 and 8-7 show typical and peak concentrations of the criteria pollutants after these developments become operational. Typical and peak concentrations from both the 50,000-bbl/day plant and the 100,000-bbl/day plant greatly exceed federal ambient standards for HC. Colorado's 24-hour SO_2 standard is also violated by peak concentrations from both plants, and the federal secondary standard for 3-hour SO_2 is exceeded by the larger oil shale plant. The topography in the area of the 50,000-bbl/day plant can allow pollutants to become incorporated in the air flow down Parachute Creek Valley and cause high levels of HC over Grand Valley.[3]

These facilities also exceed several allowable increments for non-significant deterioration. Concentrations from both plants exceed Class II 24-hour particulate levels. Peak

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[1] Refer to Section 8.4.3.

[2] Hydrocarbon standards are violated regularly in most urban areas.

[3] Interactions of the pollutants from the plants are minimal because they have been (hypothetically) sited several miles apart and are separated by elevated terrain. If the wind blows directly from one plant to the other, plumes may interact. However, concentrations which result are less than those produced by either plant under worst-case dispersion conditions. Had the plants been sited closer together, the probability of interactions would increase. Sensitivity analysis of this siting consideration will be done during the remainder of the study.

TABLE 8-5: POLLUTION CONCENTRATIONS AT RIFLE
(micrograms per cubic meter)

Pollutant, Averaging Time	Concentrations[a]					Standards[b]		
	Background	Mid-Town Point		Rural Point		Primary	Secondary	Colorado
		1980	1990[c]	1980	1990[c]			
Particulates								
Annual	12	6	20	2	3	75	60	45
24-hour		9	68	19	68	260	150	150
SO_2								
Annual	2	3	10	1	2	80		-
24-hour		9	36	9	36	365		15
3-hour		20	60	26	60		1,300	-
NO_2[d]								
Annual	5	9		4	8	100	100	
24-hour								
HC[e]								
3-hour	130	202	571	202	571	160	160	
CO								
8-hour	1,100	616	1,960	616	1,960	10,000	10,000	
1-hour		1,010	3,170	1,010	3,170	40,000	40,000	

CO = carbon monoxide HC = hydrocarbons NO_2 = nitrogen dioxide SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] No additional plants after 1980. Air impacts are assumed to stay the same.

[d] It is assumed that 10 percent of nitrogen oxide from urban sources is converted to NO_2. Refer to the Introduction to Part II.

[e] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-6: POLLUTION CONCENTRATIONS FROM A 50,000 BARRELS PER DAY TOSCO II PLANT
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]				Standards[b]				
			Peak		Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Grand Valley	Primary	Secondary	Colorado	Class I	Class II
Particulates									
Annual	12		1.2	.1	75	60	45	5	10
24-hour		3.6	41	7.6	260	150	150	10	30
SO_2									
Annual	4		3.8	.3	80			2	15
24-hour		19	19	8.6	365		15	5	100
3-hour		50	150	13		1,300		25	700
NO_2[c]									
Annual	1		3.5	.2	100	100			
HC[d]									
3-hour	130	1,125	24,290	653	160	160			

HC = hydrocarbons NO_2 = nitrogen dioxide SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical 50,000-barrels per day TOSCO II plant. Annual average background levels are considered to be the best estimate of short-term background levels.

[b] "Primary and secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 6-7: POLLUTION CONCENTRATIONS FROM A 100,000 BARRELS PER DAY TOSCO II PLANT
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]				Standards[b]				
			Peak		Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Rio Blanco	Primary	Secondary	Colorado	Class I	Class II
Particulates									
Annual	22		1.2	.1	75	60	45	5	10
24-hour		7.0	160	1.1	260	150	150	10	30
SO_2									
Annual	2		11	2.3	80			2	15
24-hour		46	131	8	365		15	5	100
3-hour		198	1,382	11		1,300		25	700
NO_2[c]									
Annual	3		4.4	.7	100	100			
HC[d]									
3-hour		8,000	52,300	9.7	160	160			

HC = hydrocarbons NO_2 = nitrogen dioxide SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical 100,000-barrels per day TOSCO II plant. Annual average background levels are considered to be the best estimate of short-term background levels.

[b] "Primary and secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 16.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

concentrations from the larger plant exceed Class II increments for 24-hour and 3-hour SO_2, and concentrations from both plants will exceed Class I increments for annual SO_2.

These PSD violations would require buffer zones for each plant. Current EPA regulations would require a 34-mile buffer zone for the larger plant and a 20-mile buffer zone for the smaller. Although the Grand Mesa and White River National Forests are within these zones, they are currently Class II areas (Figure 8-3).

2. Pollution from Towns

Rifle's predicted population increase to 6,400 and Grand Valley's increase to 4,200 will cause concentrations of urban pollutants to reach the levels shown in Tables 8-5 and 8-6. The federal HC standard, which will be exceeded by a factor greater than three, continues to be the only ambient standard violated in Rifle by 1990. Concentrations over Grand Valley will violate federal HC standards as well as Colorado's 24-hour particulate standard. Although the populations of Rifle and Grand Valley will grow somewhat by the year 2000, the resultant pollution concentrations are expected to increase less than 5 percent over 1990 values.

8.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories of potential impacts are sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

A. Sulfates

Very little is known about sulfate concentrations likely to result from western energy development. However, one study suggests that for oil shale retorting, peak conversion rates

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analyzed during the remainder of the project. See: Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment. U.S., Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

TABLE 8-8: POLLUTANT CONCENTRATIONS AT GRAND VALLEY, 1990
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]			Standards[b]		
	Background	Mid-Town Point	Rural Point	Primary	Secondary	Colorado
Particulates						
Annual	12	11	1	75	60	45
24-Hour		37	37	260	150	150
SO_2						
Annual	2	6	1	80		
24-Hour		22	20	365		15
3-Hour		36	36		1,300	
NO_2[c]						
Annual	5	17	2	100	100	
HC[d]						
3-Hour	110	141	161	160	160	
CO						
8-Hour	1,000	1,140	1,140	10,000	10,000	
1-Hour		1,570	1,870	40,000	40,000	

CO = carbon monoxide   HC = hydrocarbons NO_2 = nitrogen dioxide SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-6. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 10 percent of nitrogen oxides from urban sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

of SO_2 to sulfates in plumes is less than 1 percent.[1] Applying this ratio in the Rifle scenario results in peak sulfate concentrations of less than 1 μg/m^3. This level is well below EPA's suggested danger point of 12 μg/m^3 for a 24-hour average.[2]

B. Oxidants

Oxidants (which include such compounds as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and bromine) can be emitted from specific sources or formed in the atmosphere. For example, oxidants can be formed when HC combine with NO_x. Too little is known about the actual conversion processes which form oxidants to be able to predict concentrations from power plants. However, the relatively low peak concentrations of HC from the power plant (33 μg/m^3) suggest that an oxidant problem is unlikely to result from that source alone. An oxidant problem would more likely result from the combination of background HC and the NO_2 emitted in the power plant plume.

Based on the Nordsieck study, oxidant levels from the oil shale facilities are not expected to violate federal oxidant standards. However, oxidant problems may occur in Rifle and Grand Valley where federal 3-hour HC standards are exceeded. Since oxidants may take as much as an hour to form, this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Fine Particulates

Fine particulates (those less than 3 microns [μ] in diameter) are primarily ash and coal particles emitted by the plants.[1] Current information suggests that particulate emissions controlled by ESP have a mean diameter of less than 5μ and uncontrolled particulates have a mean diameter of about 10μ.[2] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles remaining. The high efficiency ESP's (99-percent removal) in this scenario are estimated to produce fine particulates which account for about 50 percent of the total particulate concentrations. This percentage also applies to the TOSCO II oil shale recovery facilities. Health effects from fine particulates are discussed in Section 12.6.

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[1] Nordsieck, R., *et al. Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States*. Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975. This study assumed that sulfur dioxide in the plumes was converted to sulfate at the rate of 1 percent per hour independent of humidity, clouds, or photochemically related reaction intensity. Reported results indicate peak sulfate levels ranging from 0.1 to 1.6 percent of the corresponding peak SO_2 levels from oil shale retorting. Recent work in Scandinavia suggests that acid-forming sulfates arriving in Norway are complex ammonium sulfates formed by a catalytic and/or photochemical process which varies with the season.

[2] *Ibid*.

D. Long-range Visibility

One impact of very fine particulates (0.1-1.0μ in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light which reduces the contrast between an object and its background, eventually below levels required by the human eye to distinguish the object from the background.[3] Estimates of visual ranges for this scenario are based on empirical relationships between visual distance and fine particulate concentrations.[4]

Visibility in the region of this scenario averages about 60 miles. As the facilities in this scenario become operational, average visibility will decrease to 59 miles by 1985, 58 miles by 1990, and 57 miles by 2000. Air stagnation episodes will cause substantially greater reductions.

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[1] Fine particulates produced by atmospheric chemical reactions take long enough to form so they occur long distances from the plants.

[2] Fifty percent of the mass is contained in particles this diameter. Eppright, B.R., *et al. A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station*, Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

[3] Nitrogen dioxide may also contribute to lower visibility distances because it is a colored gas (yellow-brown) and is necessary for the production of photochemical smog.

[4] Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter," *Atmospheric Environment*, Vol. 2 (September 1968), pp. 455-64. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

TABLE 8-9: SALT DEPOSITION RATES

Plant	Average Salt Deposition Rate (pounds per acre per year)		
	0-5,600 feet[a]	5,600-49,000 feet	49,000-147,000 feet
50,000-bbl/day TOSCO II	5.3	0.4	0.03
100,000-bbl/day TOSCO II	11.0	0.7	0.05
Power Plant	23.0	1.6	0.10

bbl/day = barrels per day

[a] Diameter of circles bounding the area subject to the salt deposition rate.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although ESP's will remove enough particulates for the power plant to meet emission standards, stack plumes would probably still exceed the 20-percent opacity standard.[1] Thus, plumes will be visible at the stack exit and some distance downwind. Although no opacity standards exist for oil shale retort plants, all the stacks for the TOSCO II plants will have plumes of less than 20-percent opacity. Therefore, the visibility of plumes from oil shale plants should be much less than those associated with other energy facilities.

F. Cooling Tower Salt Deposition

Estimated salt deposition rates from cooling tower drift for the three facilities in this scenario are shown in Table 8-9. These rates are relatively low and decrease rapidly beyond 5,600 feet. Some interaction of salt deposition from the plants will occur. For example, the area midway between the two oil shale plants will receive a cumulative total of 1.0 pound per acre per year. The effect of salt on the area will depend on soil conditions, rainfall, and existing vegetation.

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[1] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal unit's heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require removal of 99.9 percent of all plume particulates, which would increase electrostatic precipitator costs.

G. Cooling Tower Fogging and Icing

Fogging and icing potential in the Rifle area is uncommon during the spring, summer, and fall when relative humidities are generally low. During the winter, however, cold moist conditions are common with an average humidity of 65 percent. Fog occurs with some regularity during this season especially in areas such as hilltops and sheltered valleys. Therefore, cooling towers may cause increases in winter fogs. Since the average temperature is below freezing from December through February, increases in ice accumulations are also likely.

8.2.5 Summary

1. Air Quality Impacts

One electrical generation and two oil shale plants are projected for the Rifle scenario by the year 2000. Federal ambient standards for 3-hour HC and Colorado standards for 24-hour SO_2 will be exceeded by all three facilities. The 100,000-bbl/day TOSCO II plant will also violate federal 3-hour SO_2 standards.

Each of the facilities will violate several PSD allowable increments. Peak concentrations from the power plant will exceed Class II increments for 24-hour SO_2 and Class I increments for annual and 3-hour SO_2 and 24-hour particulates. Peak concentrations from each of the two oil shale plants will violate Class II increments for 24-hour particulates. The larger plant will violate Class II increments for 24-hour and 3-hour SO_2. All Class I increments are exceeded by both plants. Because of these violations, buffer zones would be required between each facility and any Class I area. The largest zone would be for the 100,000-bbl/day TOSCO II plant (34 miles), followed by the 50,000-bbl/day plant (20 miles), and the power plant (13.6 miles).

Population increases in Rifle and Grand Valley will add to and create pollution problems. By 1990, Colorado's 24-hour SO_2 and federal 3-hour HC standards will be violated. Several other categories of air impacts have received only preliminary attention. Our information to date suggests that oxidant and fine particulate problems may emerge. Plumes from the stacks at the power plant may be visible and exceed the 20-percent opacity standard. Long-range visibility will be reduced from the current average of 60 miles to about 57 miles by the year 2000.

TABLE 8-10: CONCENTRATIONS FROM MINIMAL EMISSION CONTROLS
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration	Standards		
		Primary	Secondary	Colorado
SO_2				
Annual	12	80		
24-hour	7[illegible]	365		15
3-hour	2,650		1,300	
Particulate				
Annual	1.2	75	60	45
24-hour	80	260	150	150
NO_x				
Annual	9.5	100	100	

NO_x = nitrogen oxides SO_2 = sulfur dioxide

2. Alternative Emission Controls

Pollution concentrations from the power plant would vary if emission control systems with other efficiencies were used.[1] For example, Table 8-10 shows maximum SO_2, particulate, and NO_x concentrations which would result if the plant used only enough control to meet New Source Performance Standards; that is, if the plant used a 97.3-percent efficient ESP with no SO_2 removal. This is in contrast to the hypothetical 99-percent efficient ESP and 80-percent efficient SO_2 scrubber postulated in this scenario. These data show that resulting concentrations would violate federal and Colorado standards for 24-hour SO_2 and would exceed the federal standard for 3-hour SO_2.

The amounts of particulate and SO_2 removal required for each plant to meet all applicable state and federal ambient standards and federal PSD increments are shown in Tables 8-11 and 8-12. This information shows that the necessary SO_2 removal efficiencies would be 92-percent for the power plant, 90-percent for the 100,000-bbl/day TOSCO II plant, and 67-percent for the 50,000-bbl/day TOSCO II plant.[2]

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[1] New Source Performance Standards have not yet been written for oil shale plants.

[2] These efficiencies appear technologically feasible. More attention will be paid to technological feasibility of highly efficient control systems during the remainder of the project.

TABLE 8-11: REQUIRED EMISSION REMOVAL TO MEET AMBIENT STANDARDS[a]
(percent)

Pollutant Averaging Time	Power Plant		50,000-bbl/day TOSCO II		100,000-bbl/day TOSCO II	
	Federal	Colorado	Federal	Colorado	Federal	Colorado
SO_2						
Annual						
24-hour		97		67		90
3-hour					32	
Particulate						
Annual						
24-hour						

bbl/day = barrels per day SO_2 = sulfur dioxide

[a] Removal efficiencies are listed for only those averaging times which would require additional removal to meet ambient standards. For example, additional removal is required for the 50,000-bbl/day TOSCO II plant to meet federal SO_2 standards.

TABLE 8-12: REQUIRED EMISSION REMOVAL TO MEET CLASS II INCREMENTS[a]
(percent)

Pollutant Averaging Time	Power Plant	50,000-bbl/day TOSCO II	100,000-bbl/day TOSCO II
SO_2			
Annual			24
24-hour	35		63
3-hour			
Particulate			
Annual			
24-hour		37	71

bbl/day = barrels per day SO_2 = sulfur dioxide

[a] Removal efficiencies are listed for only those averaging times which would require additional removal to meet ambient standards. For example, additional removal is required for the 50,000-bbl/day TOSCO II plant to meet federal SO_2 standards.

TABLE 8-13: PLANT CAPACITY TO ATTAIN AMBIENT STANDARDS

Pollutant Averaging Time	Power Plant (MWe)		TOSCO II[a] (bbl/day)		TOSCO II[b] (bbl/day)	
	Federal	Colorado	Federal	Colorado	Federal	Colorado
SO_2						
Annual	1,000		50,000		100,000	
24-hour	1,000	80	50,000	16,500	100,000	10,000
3-hour	1,000		50,000		68,000	
Particulate						
Annual	1,000	1,000	50,000	50,000	100,000	100,000
24-hour	1,000	1,000	50,000	50,000	100,000	100,000

bbl/day = barrels per day MWe = megawatts-electric SO_2 = sulfur dioxide

[a] 50,000-bbl/day plant.

[b] 100,000-bbl/day plant

Another alternative is for the plants to reduce total capacity to meet ambient standards and NSD Class II increments. As shown in Tables 8-13 and 8-14, the power plant could meet all Federal requirements by reducing capacity to 650 MWe but could not meet Colorado's ambient standards for SO_2 without reducing

TABLE 8-14: PLANT CAPACITY TO ATTAIN CLASS II INCREMENTS

Pollutant Averaging Time	Power Plant (MWe)	TOSCO II[a]	TOSCO II[b]
SO_2			
Annual	1,000	50,000	100,000
24-hour	650	50,000	76,000
3-hour	1,000	50,000	37,000
Particulate			
Annual	1,000	50,000	100,000
24-hour	1,000	31,500	29,000

MWe = megawatts-electric SO_2 = sulfur dioxide

[a] 50,000-barrels per day plant.

[b] 100,000-barrels per day plant.

capacity to 80 MWe.[1] The smaller TOSCO plant could meet federal and state standards by reducing capacity to 10,000 bbl/day.[2] In both cases, the Colorado standards are the most restrictive.

3. Data Availability

Availability and quality of data have limited the impact analysis reported in this chapter. These factors have primarily affected estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials. Expected improvements in data and analysis capacities include:

1. Improved understanding of pollutant emissions from electrical generation. This includes the effect of pollutants on visibility.
2. More information on the amounts and reactivity of trace elements from coals. This would improve estimates of fallout and rainout from plumes.

8.3 WATER IMPACTS

8.3.1 Introduction

Energy resource development facilities in the Rifle scenario are sited in the Upper Colorado River Basin. The major water sources will be the White and Colorado Rivers, but groundwater will also supply a significant part of the water requirements (see Figure 8-4). In the scenario area, annual rainfall varies between 11 and 20 inches per year depending on elevation, and annual snowfall varies between 60 and 100 inches.

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

8.3.2 Existing Conditions

A. Groundwater

The Rifle area contains both bedrock and alluvial aquifers. Bedrock aquifers are in the combined Uintah and Green River

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[1] This projection assumes concentrations are directly proportional to megawatt output.

[2] The larger TOSCO plant would require this much reduction because its emissions would be more susceptible to plume impaction, given the siting assumptions made in this scenario.

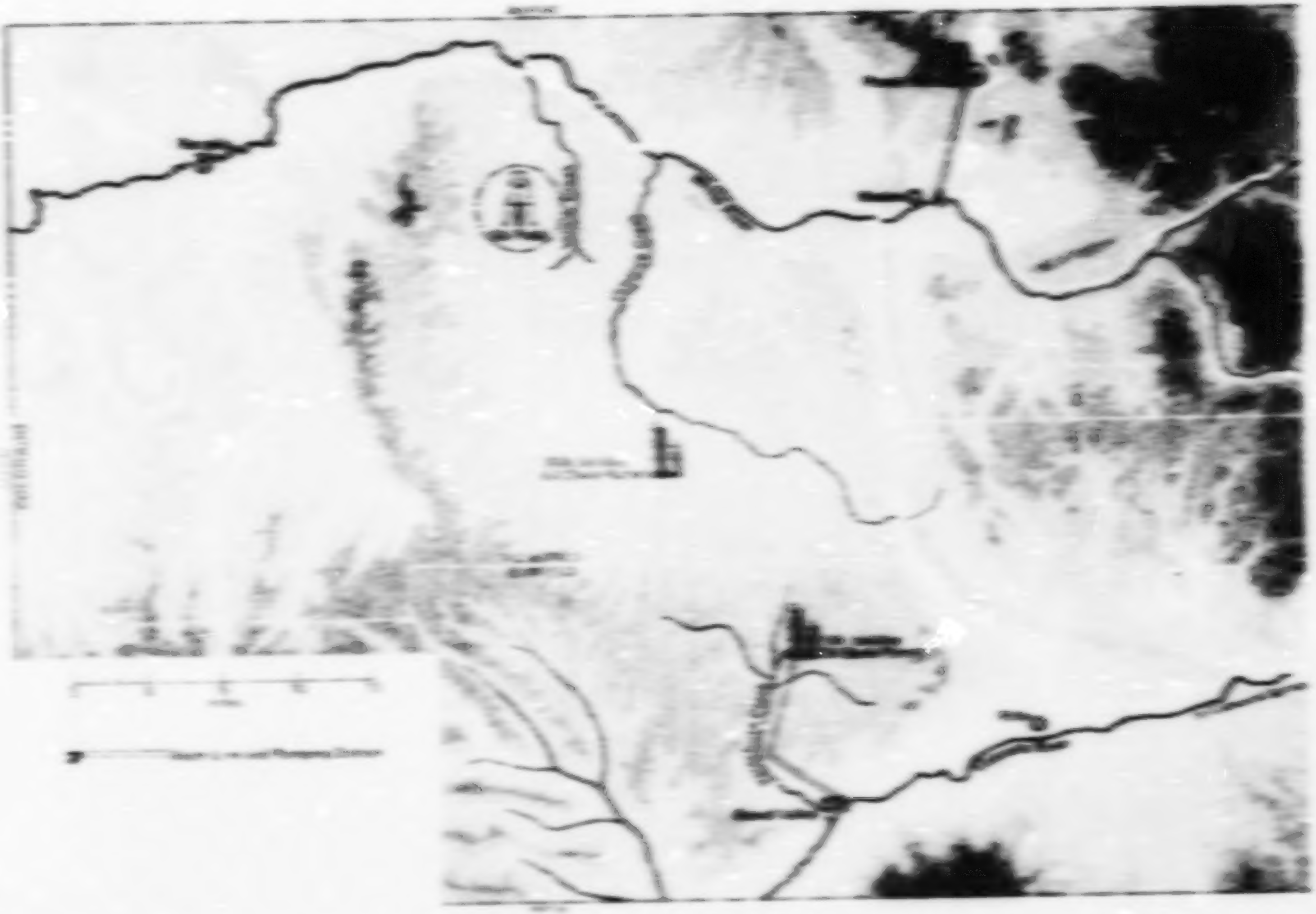

FIGURE 8-4: WATER PIPELINES FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

Formations and in the Mesa Verde Group. The Uintah and Green River aquifers are separated by the Mahogany Zone, the principal source of oil shale. Since leakage is common through the zone, the two aquifers behave as if they were parts of the same unit, although their water quality differs. The total volume of water stored in the Uintah and Green River aquifers has been estimated to be about 25 million acre-feet.[1] The flow through the portion of the aquifers in the Piceance Creek drainage Basin is estimated to be about 36 cubic feet per second (cfs).[2] Most of the recharge takes place in outcrops of the aquifers, and groundwater flow is toward the center of the Piceance Basin. Discharge is mostly from springs and into alluvial aquifers. Wells penetrating both aquifers should yield as much as 1,000 gallons per minute (gpm). The total dissolved solids (TDS) of water in the upper aquifer is generally less than 1,000 milligrams per liter (mg/l), but the TDS of water in the lower aquifer is as high as 40,000 mg/l.[3]

Aquifers in the Mesa Verde Group are important to the scenario area because this group is the projected source of coal for the power plant. Very little information is available on groundwater in the Mesa Verde Group. These aquifers, many of which are perched, occur in discontinuous beds of sandstone that are interspersed in the shales of the formation. Records[4] indicate that wells in the Mesa Verde produce less than 50 gpm in the scenario region, but no data are available on water quality for the Mesa Verde aquifers.

The alluvial aquifers associated with the Colorado and White Rivers are recharged by their respective rivers and, therefore, are highly reliable and productive sources of water. The hydrology is much the same for the Parachute and Piceance Creek aquifers; however, their productivity is relatively low, and current use is limited to providing water for livestock. Water quality in the two creek aquifers is relatively good with TDS of less than 1000 mg/l in the upper reaches. Because of decreases in the quality of recharge from the bedrock aquifers, groundwater quality in the alluvium becomes progressively worse downstream, eventually reaching 3,000 mg/ℓ TDS.

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[1] U.S., Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program, 3 vols. Washington, D.C.: Government Printing Office, 1973, Vol. I, p. II-141.

[2] Weeks, John B., et al. Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado. U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974, p. 34.

[3] Ibid., p. 40.

[4] Colorado Land Use Commission. Colorado Land Use Map Folio. Denver, Colo.: Colorado Land Use Commission, 1974.

B. Surface Water

As shown in Figure 8-4, the White and Colorado Rivers are the major surface-water supply sources for energy development in the Rifle scenario. Flow allocations in both of these rivers are governed by the Colorado River Compact,[1] the Upper Colorado River Basin Compact,[2] and the Mexico Treaty of 1944[3] as well as the laws of the State of Colorado. Colorado's share of the flow in the Upper Colorado River Basin (UCRB) is determined with reference to the natural flow of the Colorado River at Lees Ferry, Arizona. This flow has been estimated from 5.25 million to 6.3 million acre-ft/yr; the most widely accepted estimate is that made by the Department of Interior at 5.8 million acre-ft/yr.[4] Using that value, Colorado's share of the flow is about 3 million acre-ft/yr. Near Rifle, the Colorado River has an average flow of 2.8 million acre-ft/yr, and the White River has 455,000 acre-ft/yr, so that these two rivers can provide Colorado's share of the UCRB apportionment.

Present uses of UCRB water in Colorado are shown in Table 8-15. The main use is for irrigation, but a significant portion is diverted to municipal use in the Denver area. Although the average annual supply greatly exceeds the estimated water use in the Rifle area, legal commitments and in-stream needs account for all but about 10 percent of the remaining portion.

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[1] Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[2] Upper Colorado River Basin Compact of 1948, 63 Stat. 31 (1949).

[3] Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

[4] U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974, p. 11.

TABLE 8-15: WATER USE IN THE UPPER COLORADO RIVER BASIN PORTION OF THE STATE OF COLORADO (in thousands of acre-feet)[a]

	Green River Subbasin	Upper Main Stem Subbasin
Average Annual Water Supply		
Inflow to region[b]	255	0
Undepleted water yield	1,776	6,738
Total Water Supply	2,031	6,738
Estimated 1975 Water Use		
Estimated exports	0	614[c]
Irrigation	89	779
Municipal and industrial including rural	2	14
Minerals	4	8
Thermal electric	10	4
Recreation fish and wildlife	3	8
Other	5	11
Consumptive conveyance losses	22	175
Reservoir evaporation	2	37
Total depletions[d]	137	1,650

[a] U.S., Department of the Interior, Bureau of Reclamation, Westwide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 42.

[b] Reflects the effects of depletions upstream of state lines.

[c] Includes intersubbasin transfer to San Juan River and interbasin transfer to the Denver, Colorado area.

[d] Includes Colorado's remaining share of mainstem reservoir evaporation.

Water quality in the White and Colorado Rivers is shown in Table 8-16. Also shown are water quality data for Piceance and Parachute creeks, both of which may be impacted by energy development. Water quality is generally good in the White and Colorado Rivers and in Parachute Creek, but TDS and hardness levels are high in Piceance Creek, primarily due to bicarbonates and sodium.

TABLE 8-16: WATER QUALITY AND FLOW FOR RIFLE VICINITY

cfs = cubic feet per second   mg/l = milligrams per liter   pH = acidity/alkalinity   < = smaller than

TABLE 8-17: WATER REQUIREMENTS FOR ENERGY DEVELOPMENT

Use	Size	Requirement[a] (acre-ft/yr)	
		ERDS[b]	WPA[c]
Power Plant	1,000 MWe	14,000	13,360
Oil Shale Retort (TOSCO II)	50,000 bbl/day	7,210	6,140
Oil Shale Retort (TOSCO II)	100,000 bbl/day	14,420	12,280

bbl/day = barrels per day
ERDS = Energy Resource Development System
MWe = megawatts-electric
WPA = Water Purification Associates

[a] Requirements are based on an assumed load factor of 100 percent. Although not realistic for sustained operation, this load factor will indicate the maximum water demand for these facilities.

[b] Chapter 3 of White, Irvin L., *et al*. *Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c] From Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The load factors assumed in the report are different for different technologies. Water consumption was changed to correspond to 100 percent load factor in this table.

8.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements hypothesized for the Rifle scenario are shown in Table 8-17.[1] Two sets of data are presented. The Energy Resource Development System data are based on secondary sources (including impact statements, Federal Power Commission docket filings, and recently published data accumulations[1]) and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water use requirements and take into account the moisture content of the coal being used and local meteorological data.[2] The consumptive use of the water required for these facilities is shown in Figure 8-5. Cooling consumes the most water in power generation, while for oil shale processing, cooling, and solid waste disposal consume comparable amounts.

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[1] Water requirements for tertiary oil recovery have not been included.

Additional water will be required for oil shale mines and for spent shale reclamation. These requirements are based on an irrigation rate of 24 inches per year for 5 years[3] and are shown in Table 8-18.

TABLE 8-18: WATER REQUIREMENTS FOR RECLAMATION[a]

Mine	Acres Disturbed Per Year	Maximum Acres Under Irrigation	Water Requirement (acre-ft/yr)
Power Plant	275	1,375	2,750
Underground Oil Shale	150	750	1,500
Surface Oil Shale	75	375	750
Total	500	2,500	5,000

[a] Based on an irrigation rate of 24 inches per year for 5 years.

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[1] University of Oklahoma, Science and Public Policy Program, Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975. Radian Corporation. A Western Regional Energy Development Study, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

[2] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. See Appendix B.

[3] Cook, C. Wayne. Surface Rehabilitation of Land Disturbances Resulting from Oil Shale Development. Ft. Collins, Colo.: Colorado State University, Environmental Resources Center, 1974, p. 50.

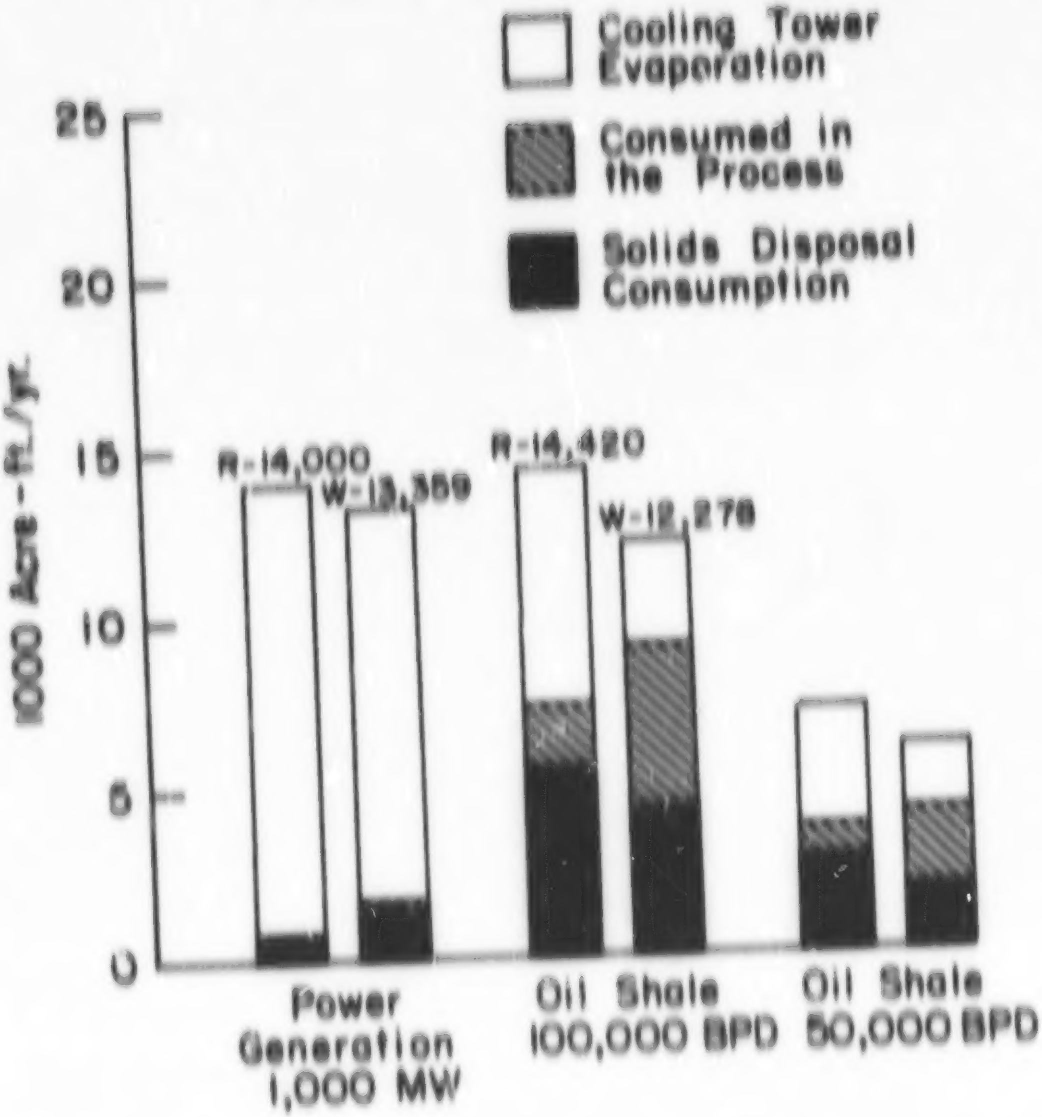

FIGURE 8-5: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

TABLE 8-19: INCREASED MUNICIPAL WATER SUPPLY REQUIREMENTS (acre-ft/yr)[a]

Location	Per Capita Usage			
	1975	1980	1990	2000
Rifle	130	65	570	610
Grand Valley	70	25	300	320
Glenwood Springs	120	25	80	120
Grand Junction	165	775	2,680	3,820
Meeker	150	810	1,110	1,200
Rangely	85	480	380	410
Rural	80	120	450	510

[a] Based on 130 percent of reported wastewater flow. See Table 8-22.

As shown in Figure 8-1, water for the power plant will be taken from the White River near Meeker. Water that has been released from a new upstream, off-channel impoundment will be withdrawn from the Colorado River near Grand Valley to supply the 50,000 barrels per day (bbl/day) oil shale plant. This new impoundment will be filled with flood flows from the Colorado River. The 100,000-bbl/day oil shale plant will use groundwater from dewatering the oil shale mines as process water.

B. Municipalities

The increased population associated with energy development will require additional water supply facilities. An estimated total of 7,000 acre-ft/yr of water will be required by the year 2000. This requirement has been broken down by municipality in Table 8-19. Water for municipal use will probably be withdrawn from Colorado's allocation of the Colorado River either through a direct intake of river water or from wells in alluvial aquifers. In either case, permits must be obtained from the State of Colorado to withdraw this water.

8.3.4 Effluents

A. Energy Facilities

The quantities and types of wastes from energy technologies hypothesized at Rifle are shown in Table 8-20. Effluents from the shale retorts are more than 100 times those from the power plant and are primarily spent shale. Dust control at the 50,000-bbl/day shale plant produces effluent quantities comparable to power plant flue gas desulfurization and ash

TABLE 8-26: RESIDUALS GENERATED BY ENERGY FACILITIES AT RIFLE[a]

Residual Source	Stream Content[b]	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (gpm)
Power Plant total		1,490	861	105
Boiler demineralizer waste	S	0.4	0.2	0.04
Treatment waste	I	64	26	6
Flue gas desulfurization		743	297	74
Bottom ash disposal	I	143	109	6
Fly ash disposal	I	543	431	19
50,000-Bbl/Day Oil Shale Retort total		62,100	54,000	1,350
Spent shale disposal		61,100	53,600	1,250
Venturi scrubber dust control		968	368	100
100,000-Bbl/Day Oil Shale Retort total		124,200	108,000	2,700
Spent shale disposal		122,300	107,300	2,500
Venturi scrubber dust control		1,940	736	200

Bbl/Day = barrels per day gpm = gallons per minute tpd = tons per day

[a] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The load factors assumed in the report are different for different technologies. Water consumption was changed to correspond to 100 percent load factor in this table.

[b] S = soluble inorganic
I = insoluble inorganic

TABLE 8-21: WASTEWATER TREATMENT CHARACTERISTICS FOR TOWNS AFFECTED BY THE RIFLE SCENARIO[a]

Town	Type of Treatment	Design Load (MMgpd)	Present Flow (MMgpd)	Future Facilities
Rifle	Aerated lagoon system	.3	.220	Preparing 201[b] plan
Grand Valley	Extended aeration package plant	.03	overloaded	Preparing 201 plan
Glenwood Springs	Trickling filter plant	1.3	.5	Completed 201 plan
Grand Junction	Trickling filter plant	7.3	4.23	Completed 201 plan
Meeker	Extended aeration	0.2	0.24	Currently under expansion to 0.4 MMgpd activated sludge + tertiary treatment
Rangely	Aerated lagoon	0.36	0.13	Design phase for expansion to 1.0 MMgpd with aerated lagoons

MMgpd = million gallons per day

[a] From telephone conversation with the Colorado Water Quality Control Commission.

[b] Refers to Section 201 of the Federal Water Pollution Control Act Amendments of 1972, §§201, 33 U.S.C.A. §§1281 (Supp. 1976) wherein federal funds are available for the planning, design, and construction of wastewater treatment facilities.

disposal. Other residual quantities are insignificant. All of these waste streams are ponded; there are no intentional releases to surface or groundwater systems.

All effluent streams from the facilities will be discharged into clay-lined, on-site evaporative holding ponds. Runoff prevention systems will be installed in all areas that have a pollutant potential. Runoff will be directed to either a holding pond or a water treatment facility.

B. Municipalities

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drainfields), and the urban population will require waste treatment facilities. The current status of wastewater treatment facilities in the municipalities most affected by energy development activities is indicated in Table 8-21. The waste water generated by the population increases associated with energy development is shown in Table 8-22.

TABLE 8-22: EXPECTED INCREASES IN WASTEWATER FLOW

	Increased Flow Above 1975 Level[a] (million gallons per day)					
Year	Rifle[b]	Grand[c] Valley	Glenwood[d] Springs	Grand[e] Junction	Meeker[f]	Rangely[g]
1980	0.05	0.02	0.02	0.54	0.55	0.33
1990	0.39	0.21	0.05	1.9	0.75	0.26
2000	0.42	0.22	0.08	2.6	0.81	0.28

[a] From telephone conversation--Colorado Water Quality Control Commission.

[b] 100 gallons per capita per day (gcd).

[c] 56 gcd.

[d] 91 gcd.

[e] 128 gcd.

[f] 114 gcd.

[g] 65 gcd.

Based on current treatment facilities capabilities, all the communities impacted in this scenario, except Glenwood Springs and Grand Junction, will require new wastewater treatment facilities to accommodate new population due to energy developments. New facilities will need to use "best practicable" waste treatment technologies to conform to 1983 standards and must have allowance for recycling or zero discharge of pollutants to meet 1985 standards.[1] The 1985 standards could be met by using effluents from the waste treatment facility for industrial process make-up water or for irrigating local farmland.

8.3.5 Impacts

A. Impacts to 1980

The only facilities to be in operation by 1980 are the 1,000-MWe (megawatts-electric) power plant and its associated underground coal mine.

1. Underground Coal Mine

The coal mine will use surface-water sources and should not result in the depletion of any regional groundwater aquifers. However, the mine openings will probably intercept some of the groundwater flow in the Mesa Verde Group, and any associated dewatering operations could also cause depletion of local aquifers, particularly if the aquifers are perched.

Since the coal mine will be located on a natural watershed divide, runoff affected by the mining process can be trapped without disturbing natural surface-water drainage. Also, because this is an underground mine, only a small area will be needed for surface facilities that cause changes in water quality. Water affected by these facilities will be trapped and introduced into the water treatment facilities at the power plant.

2. Power Plant

Construction activities at the power plant will remove vegetation and disturb the soil. These activities have an effect on surface-water quality. The major effect will be from increases in the sediment load of local runoff. Maintenance areas and petroleum products storage facilities will also be needed to support construction equipment. Areas for the storage of other construction-related materials (such as aggregate for a concrete batch plant) may be required as well. All these facilities have the potential for contaminating runoff. Runoff control methods will be instituted at all the potential sources of contaminants. Runoff will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water, but some of the water may be used for dust control.

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[1] Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

The power plant facility will use about 14,000 acre-feet of surface water annually (see Table 8-17). This water will come from the White River near Meeker. A 20-acre surface reservoir to be constructed at the plant site will contain a 21-day supply of water (about 800 acre-feet). This water will be used during extremely low-flow periods in the White River, but the plant will generally not draw water solely from the reservoir for more than 14 consecutive days. The plant requires approximately 20 cubic feet of water per second. This would consume about 14 percent of the lowest recorded flow in the White River at Meeker.

Since water for the coal-fired power plant will be obtained from surface-water sources, excessive withdrawals and aquifer depletions are not expected to be major problems. In fact, leakage from fresh-water storage ponds should have the beneficial effect of recharging local perched aquifers.

Approximate quantities of effluents expected from the operation of the power plant are given in Table 8-20. These effluents will be discharged into clay-lined retention ponds to reduce the potential for pollution of local surface waters or groundwaters, although some leakage from these ponds could occur and pollute groundwater.

3. Municipal Facilities

The effects of energy development-related population growth on area municipal facilities in terms of increased water supply and wastewater treatment demand were shown in Tables 8-19 and 8-21.

Small communities will be significantly affected by large increases in water and wastewater service requirements. Updating treatment facilities to meet expected population demands may cost more per capita in a small municipality than in a large city. Under present law, pollutants from the sewage treatment plant may discharge to surface waters until 1985. If a reliable treatment scheme can be devised, there should be no significant pollution from this practice. Where population growth occurs in rural areas having no centralized treatment facilities, groundwater quality may be decreased by septic tank and drainfield systems. The substrate has a natural capacity for renovation of septic tank effluent, but this capacity can be exceeded if septic tank density becomes too great.

Other environmental effects to be expected as a result of population growth include a decrease in surface-water quality stemming from urban runoff. If contaminated runoff recharges aquifers, then groundwater quality may be affected as well.

Leachates from additional municipal solid waste disposal sites can also contaminate both groundwater and surface water.

B. Impacts to 1990

The 50,000-bbl/day oil shale plant will begin operations in 1985. Construction of the 100,000-bbl/day oil shale plant will begin in 1984, and the plant will go on-line in 1990. The 1,000-MWe power plant will continue operation throughout this period. The tertiary recovery operations at the oilfield will also begin before 1990, but because of data deficiencies, their impacts will not be described in this report.

1. Mines

The two oil shale mines will have several impacts on the bedrock groundwater aquifers. Mine dewatering operations at the 100,000-bbl/day facility in the Piceance Creek Basin are expected ultimately to intercept at least 14 cfs of the bedrock aquifer flow.[1] This is 39 percent of the 36 cfs flow estimated for the Green River aquifer in the Piceance Creek Basin.[2] Interception of this amount of flow will cause several springs and seeps to dry up, and the recharge to alluvial aquifers will also be reduced. At the 50,000-bbl/day plant, mining operations will deplete the bedrock aquifers by 420 acre-ft/yr (0.58 cfs), which will lower the local water table below the bed of Parachute Creek and thus eliminate its base flow.[3]

The effects of the underground coal mine are expected to be about the same as those described for the previous period. However, the extent of the impacts will increase as expanded mine openings intercept more aquifers and/or remove more of the original aquifer, resulting in greater interruption of groundwater flow. Also, mine subsidence may begin to set in during this decade and may lead to such effects as topographic and drainage pattern changes, disruption of groundwater flow in the overburden, and possibly mixing of fresh and saline aquifers.

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[1] Weeks, John B., *et al.* *Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado.* U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974, p. 4.

[2] *Ibid.*, p. 34.

[3] U.S., Department of the Interior, Bureau of Land Management. *Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado.* Washington, D.C.: Bureau of Land Management, 1975, p. 34.

vegetation has been established, which could increase runoff as much as 1.4 acre-ft per acre of disposal pile.[1] However, this increase in runoff will appear as a loss of flow in the local streams during the life of the plant because the water will be caught by retention facilities and treated for use as process make-up water. These facilities will cause a portion of the natural watershed to be effectively removed from the basin, thus causing the flow decrease in local streams. After vegetation is established and runoff quality has been shown to be acceptable, the retention facility will be deactivated and runoff will be returned to these streams.

3. Municipal Facilities

If municipalities install sewage treatment facilities that meet the goal of zero discharge of pollutants by 1985, the increased municipal effluent will have little effect on groundwater systems. A possible exception is excess leakage from municipal sewer lines that could contaminate shallow aquifers. Population growth in rural areas may also have an impact on aquifers. In areas of high population density where septic tank and drainfield disposal methods are used, the cumulative effect of the septic tanks may exceed the capacity of the soils to renovate the drainfield effluent. The result would be the direct infiltration of effluent into aquifers, thereby lowering groundwater quality. Other sources of contamination for both surface and groundwater are urban runoff and leachate from solid waste disposal sites.

Municipal water supply requirements will have to be met through increases in service systems and treatment facilities. The quantities of the increases in water supply and wastewater are shown in Table 8-19 and 8-21.

C. Impacts to 2000

The effects of the 100,000-bbl/day oil shale plant will begin after the plant becomes operational in 1990. The impacts of the other oil shale plant and the coal mine and power plant will continue as in the preceding decade.

1. Mines

Continued operations at the coal mine and the 50,000-bbl/day oil shale plant are expected to increase the effects on the bedrock aquifers described earlier. Water added to the spent

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[1] Weeks, John B., *et al.* *Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado.* U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974.

3. Energy Conversion Facilities

The 1,000-MWe power plant will use surface-water supplies and will not contribute to depletion of aquifers in the area. Leakage from water storage ponds will have the continued beneficial effect of recharging local aquifers with high quality water that will tend to dilute lower quality water. Lower quality recharge would be expected from cooling tower and sanitary effluent ponds and from scrubber sludge and ash disposal sites. This may result in contamination of local Mesa Verde aquifers. The effect of the power plant on the flow in the White River, as described earlier, will continue throughout this decade.

Since water for operation of the 50,000-bbl/day oil shale plant will be taken from surface water, the water requirements of this plant will have minimal negative impact on groundwater supplies. Although water storage ponds at the site may provide beneficial recharge to the bedrock aquifers, leakage from effluent disposal ponds may lower groundwater quality. If the spent (processed) oil shale from the 50,000-bbl/day plant is deposited in gullies as planned, infiltrating precipitation and water added for revegetation may leach trace elements and dissolved salts into both bedrock and alluvial aquifers (the latter by pollution of streamflow which becomes recharge to the alluvial aquifers).

The water supply system envisioned for the 50,000-bbl/day oil shale plant on Parachute Creek will have little effect on surface flows. Water is postulated to be released from an upstream impoundment and removed near the confluence of the Colorado River and Parachute Creek. The impoundment will be offstream and will be filled with flood flows from the Colorado River. There should be no measurable adverse environmental impact from this water supply system provided the impoundment design is adequate to handle extreme low-flow periods. If the plant were to withdraw process water without a corresponding impoundment release, the plant requirement of 22.7 cfs is equivalent to 1.8 percent of the minimum low flow of record near Cameo, Colorado (the closest gaging station with adequate records). Even during such an extreme event, changes caused by the process withdrawals would be small.

Energy conversion activities also increase surface runoff. The large areas used for spent shale disposal will contribute to this increase as will the process facilities and roads. Also, the oil shale disposal piles may become semi-impermeable until

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[1] U.S., Department of the Interior, Bureau of Land Management, *Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado* (Washington, D.C.: Bureau of Land Management, 1975), p. 34.

shale during revegetation, as well as natural precipitation, will leach trace elements, dissolved salts, and other contaminants from the shale. This contaminated water may then recharge the lower Green River aquifer, which has low water quality (high TDS) even in natural conditions.

The impact on surface water will increase as the area of disturbed land caused by mining activities increases. Recharge into Yellow and Piceance Creeks (Figure 8-1) will be further diminished, and water quality will be lowered in the groundwater recharge areas.

2. Energy Conversion Facilities

The effects of the power plant and coal mine, the tertiary recovery operation, and the 50,000-bbl/day oil shale plant will continue during the 1990-2000 period.

The onset of operations of the 100,000-bbl/day oil shale plant in 1990 will mark the beginning of bedrock aquifer depletion in the drainage basin of Piceance Creek. As noted in an earlier section, about 23 cfs will be required for plant operations. Aquifer modeling studies by the U.S. Geological Survey[1] indicate that most, if not all, of this water can be taken from dewatering activities at the mine. Water levels in the area around the mine will decline and a 10-mile stretch of Piceance Creek near the mine will begin to lose flow to groundwater recharge. Water flowing into this stretch from upstream will probably all go to aquifer recharge and there will probably be no flow in the creek bed. One of the chief effects of this flow loss will be a lowering of the quality of water in the creek downstream from the mine. The stream in that area gains poor quality groundwater, but under natural conditions, this water is diluted by good quality water from the upper reaches of the stream. When this good quality streamflow is lost to the bedrock aquifer because of dewatering, the benefits of dilution will be lost. Also, springs and seeps may be expected to dry up in the area where water levels decline because of dewatering, particularly in the "losing" stretch of the stream. These water losses and water quality effects will not occur immediately when the mine is opened but will gradually build up over the 30-year life of the operation. The conditions described will exist at the time of plant shutdown and therefore represent a "worse-case" situation.

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[1] Weeks, John B., et al. *Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado*, U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974.

The spent shale from the 100,000-bbl/day operation will be deposited in mined-out areas and gullies. Water from direct precipitation and the water added for revegetation purposes may leach trace elements or other contaminants from the spent shale. Leakage from the toe of the deposits will be collected and processed, but some leachate may infiltrate bedrock aquifers and contaminate the groundwater. Runoff characteristics from reclaimed land must be monitored to insure that an acceptable level of water quality is being achieved.

Because of Public Law 92-500, which has a goal of zero discharge of pollutants by 1985, the only surface-water effects associated with effluent disposal at the energy facilities will be the result of unplanned occurrences. Ponds used for the ultimate disposal of cooling-tower blowdown, sanitary effluent, and scrubber sludge will continue to fill. The associated water will be evaporated or may leak into the pond liner material carrying some of the dissolved constituents with it. There will be the continuing possibility that some harmful constituents will reach the groundwater system and cause a degradation of both surface and groundwater supplies. Clay adsorption in the pond liner or, where it occurs, in the clay substrate will reduce the possibility of trace element contamination but will not reduce the total dissolved solids content.

3. Municipal Facilities

Increased urban and rural population growth in the 1990-2000 decade will produce qualitatively similar but quantitatively greater effects as compared with the preceding decade. Municipal facilities will experience progressively increasing demands for water supply and wastewater treatment. Water supplies will continue to be charged against Colorado's share of Upper Basin surface water, whether taken from streams or alluvial aquifers. Wastewater treatment facilities will be changed from discharging to local streams to recycling or land application of effluents. Recycled water may help diminish the water supply demands placed on local sources by the hypothesized energy development facilities.

D. Impacts After 2000

1. Mines

After operations cease, the oil shale and coal mines may subside over the long term, resulting in minor changes in topography and drainage patterns as well as changes in groundwater flow patterns in the overburden. In addition, the coal mine may produce acid water. However, insufficient groundwater data preclude the evaluation of this potential problem. The low-sulfur content of the coal may reduce this probability.

2. Energy Conversion Facilities

After the plants are decommissioned, the facilities will remain. Leakage from effluent disposal ponds may continue to recharge and contaminate groundwater systems long after operations cease unless the sites are properly maintained. Likewise, the dikes around the evaporative ponds may lose their protective vegetation and erode, and the dikes may breach as a result. Subsequently, materials within the pond site will erode and enter the surface-water system.

3. Municipal Facilities

As municipal wastewater plants are upgraded, the quality of effluents will improve and the impacts on groundwater will lessen. Further, as rural areas become more densely populated, more of these areas will switch from septic tanks to municipal wastewater treatment systems. The decreased septic tank load will alleviate the associated groundwater degradation problem. However, those areas remaining on septic tanks will pose a continued hazard to local groundwater systems.

8.3.6 Summary of Significant Impacts

The oil shale mines will have an impact on both groundwater and surface water hydrology. A significant portion of the local groundwater will be removed by mine dewatering activities. This depletion will decrease the groundwater supply to surface streams and to springs and seeps.

Coal mine subsidence will change local overland water flow patterns and may create depressions that will store water. Due to the lack of groundwater data, an evaluation of the possibility of acid-mine drainage has not been made during this first year.

Cumulative water requirements of energy conversion facilities will be about 50,000 acre-ft/yr. The impact of surface water withdrawal on water availability is not a major local issue, especially for the Colorado River. However, as noted earlier, the groundwater withdrawals in Piceance Creek will cause depletion of flow to springs and seeps as well as greatly reduce the groundwaher recharge of surface streams.

Runoff will decrease during facility construction and will remain measurably less than current levels after the facilities are completed due to trapping of this runoff to guard against water quality deterioration.

One of the most significant impacts will be the interception of groundwater flow in the Piceance Creek Basin. The 100,000-bbl/day oil shale plant will withdraw 70 percent of the aquifer flow, none of which will be released from the plant site. Removal of this quantity of flow (25 cfs) will not only lower water levels in the aquifer but will reduce or eliminate flow from springs and seeps. This will result in the reduction of the base flow of Piceance Creek to 30 percent of its original amount and will eliminate flow in the creek at least part of the time. The quantity of base flow lost will also be reflected as a loss of flow in the White River.

Over the long term, spent shale deposits are likely to have an impact on both groundwater and surface water. The hydrology of the upper parts of the affected stream basins will be changed by filling gullies with spent shale. After revegetation, natural precipitation will continue to leach trace elements. Some of this leachate may recharge bedrock aquifers, and some will surface at the toe of the piles and enter surface-water systems. Runoff from spent shale piles will be trapped and cycled for process water, but only for the life of the plants.

Waste disposal ponds at the various energy conversion plant sites will also pose a long-term pollution potential to both groundwater and surface water systems. The berms that impound the ponds may ultimately be destroyed by erosion, and the pond contents (soluble solids, ash, toxic metals, and other wastes) may be released to surface water. The pond liners are designed to be effective for the life of the plant, but they may not prevent escape of the pond contents over the long term. Leaching of pond contents would result in infiltration into the subsurface and recharge to local aquifers. If the vertical permeability is low, the leachate will migrate laterally, discharge into stream basins, and ultimately contaminate surface streams.

The impact of energy development on municipal water facilities depends on the size of the communities involved. Larger capacity treatment facilities and new treatment schemes will be required for water supply and wastewater treatment. The water supply requirements will put a greater demand on the surface-water resource even though wastewater effluents may eventually be recycled for industrial uses.

8.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

8.4.1 Introduction

The social, economic, and political effects resulting from energy developments in the Rifle scenario will occur primarily in Garfield and Rio Blanco Counties and the city of Grand Junction. At present, the area population is concentrated in the eastern portion of the counties; the hypothetical energy developments will be located in the western portion of the counties. Most of the anticipated social, economic, and political impacts will result either directly or indirectly from the population increase that will come with energy development. This section describes and analyzes existing conditions in the area and the changes likely to accompany energy development.

8.4.2 Existing Conditions[1]

Garfield and Rio Blanco Counties occupy 6,254 square miles and had a combined 1970 population of 19,663, giving the region a population density of 3.1 people per square mile. Colorado's overall density is 21.2 people per square mile. The population of the area has increased in the last decade but not on a comparable level with the state (14.5 percent increase for the two counties as compared with 25.8 percent for the state). Speculation and anticipation concerning oil shale production in the area has been a major cause for this population growth. Further, Rio Blanco County's population declined by 6 percent during the decade, primarily due to net out-migration. About one-half of the residents in the two counties live in unincorporated areas. Populations and population changes for the area counties and towns are shown in Table 8-23.

TABLE 8-23: POPULATIONS OF COUNTIES AND TOWNS IN THE RIFLE VICINITY

Location	1974[a]	1970	1960
Rio Blanco County	5,200	4,842	5,150
Meeker	2,000	1,597	1,655
Rangely	1,725	1,591	1,464
Garfield County	16,500	14,821	12,017
Glenwood Springs	4,646	4,106	3,637
Rifle	2,402	2,150	2,135
Carbondale	1,600	726	612
New Castle	618	499	447
Silt	720	434	386
Grand Valley	360	360	245
Mesa County	57,200	54,374	50,715
Grand Junction	26,400	20,170	18,694

[a]Sources: U.S., Department of Commerce, Bureau of the Census, "Estimates of the Population of Colorado Counties and Metropolitan Areas: July 1, 1973 and July 1, 1974," Current Population Reports, Series P-26, No. 103 (April 1975); Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee, Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII (Denver, Colo.: Mountain Plains Federal Regional Council, 1975).

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[1] For a detailed history and current description of the scenario area, see Ashland Oil, Inc.; Shell Oil Co., Operator. Oil Shale Tract C-b, Socio-Economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program. n.p.: March 1976, Vol. 1.

TABLE 8-24: EMPLOYMENT DISTRIBUTION BY INDUSTRY, GARFIELD AND RIO BLANCO, 1970

Industry	Garfield	Rio Blanco	Two-County Area (%)
Agriculture	558	306	11
Mining	395	280	8.6
Construction	678	152	10.6
Manufacturing	166[a]	42[b]	2.7
Transportation and communication	214	32	3.1
Utilities	186	62	3.2
Wholesale trade	153	53	2.6
Retail trade	1,242	241	18.9
F.I.R.E.[c]	265	56	4.1
Services	1,236	603[d]	23.4
Government and education	564	153	9.1
Not reported	208	0	2.7
Total	5,865	1,980	100

Sources: U.S., Department of Commerce, Bureau of Economic Affairs and U.S., Department of the Interior, Bureau of Land Management.

[a] Mostly food processing.

[b] Mostly petroleum refining.

[c] Finance, Insurance, and Real Estate.

[d] Mostly professional services.

Employment by industry in the two counties is shown in Table 8-24. Tourist-related employment is centered in Glenwood Springs, which is on the route to Aspen and Vail.

Garfield and Rio Blanco Counties are each governed by a Board of County Commissioners. Both counties have planning departments and countywide zoning regulations (see Table 8-25). Both also belong to a council of governments made up of elected officials from these counties and Moffat and Mesa Counties. This council of governments has focused much of its attention on oil shale development within the area. According to a survey of

TABLE 8-35: LAND USE REGULATIONS, GARFIELD AND RIO BLANCO COUNTIES AND LOCAL MUNICIPALITIES, 1975

Location	Planning Commission	Zoning Ordinance	Mobile Home Regulations	Subdivision Regulations	Building Code
Garfield County	Y	Y	Y	Y	Y
Carbondale	Y	Y	N	Y	Y
Glenwood Springs	Y	Y	Y	Y	Y
Grand Valley	Imminent	N	N	N	N
New Castle	Y	Y	N	N	Y
Rifle	Y	Y	Y	Y	Y
Silt	Imminent	Y	N	N	Y
Rio Blanco County	Y	Y	Y	Y	Y(U.B.C.)[a]
Meeker	Y	Y	Y	Y	County
Rangely	Y	Y	Y	Y	County

N = absence of commission or regulation.
Y = county or community does have the commission or regulation.

Source: THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974 and Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[a] Uniform Building Code.

residents and officials, stringent land-use controls are favored in Garfield County and opposed in Rio Blanco County.[1]

Carbondale, Glenwood Springs, New Castle, Silt, Rifle, and Grand Valley are the incorporated cities in Garfield County. Carbondale, Grand Valley, and Rifle are governed by a mayor and council. All three also have a professional city manager, but only Carbondale has a professional planner. (Carbondale has recently grown because of energy development in nearby Pitkin County.) Public services include water, sewers, public safety, and fire protection.[2] Apparently, current services are operating at or near capacity; however, expansion is either under way or being discussed in all three cities.

Meeker and Rangely are incorporated cities in Rio Blanco County. Both are governed by a mayor and council. Meeker has a city manager and Rangely has a town administrator, but neither has a professional planner. Public services in Meeker include water, sewers (provided by a separate district), a volunteer fire department, and public safety. Rangely provides the same services except that it is just beginning to develop its sewer system.

Education for the counties and municipalities is provided by separate school districts. Other special districts provide for sanitation, fire protection, and hospital.

8.4.3 Population Impacts

The first major energy-related impact on western Colorado will be from construction workers associated with the coal mine and power plant complex, followed in 1978 by oil well drilling personnel. All construction in this scenario will be completed before 1990. Population changes were estimated by means of an economic base model, the employment data from the Bechtel Corporation[3] in Table 8-26, and a set of multipliers for construction

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[1] VTN Colorado, Inc. *Socioeconomic and Environmental Land Use Survey: Moffat, Routt, and Rio Blanco Counties, Colorado. Summary Report*. Denver, Colo.: VTN Colorado, 1975, p. 160.

[2] Sewer service in Carbondale and fire protection in Grand Valley are provided by separate districts. Rifle is now forming a separate fire protection district.

[3] Carasso, M., *et al*. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 8-26: CONSTRUCTION AND OPERATION EMPLOYMENT FOR RIFLE SCENARIO, 1975-2000

Year	Construction	Operation	Total
1975	157		157
1976	465		465
1977	720	150	870
1978	1,360	333	1,693
1979	2,927	665	3,592
1980	4,465	1,331	5,796
1981	4,856	1,741	6,597
1982	5,572	2,150	7,722
1983	5,161	2,560	7,721
1984	2,765	2,968	5,733
1985	623	4,297	4,920
1986	1,877	4,297	6,174
1987	3,310	4,297	7,607
1988	3,356	4,297	7,653
1989	1,871	4,297	6,168
1990	0	6,132	6,132
1990-2000	0	6,132	6,132

Source: Carasso, M., *et al.* *The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975.

and for operation phases.[1] Further, the overall population estimates were distributed spatially among the urban centers in and around Garfield County (Table 8-27 and Figures 8-6 and 8-7). The

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[1] Construction-phase service/basic multipliers increase from 0.3 in 1975 to 0.7 in 1982 and remain constant thereafter; operation-phase multipliers begin at 0.4 in 1977 and rise to 1.2 by 1986. These values were adapted from Crawford, A.B., H.H. Fullerton, and W.C. Lewis. *Socio-Economic Impact Study of Oil Shale Development in the Uintah Basin*, for White River Shale Project. Providence, Utah: Western Environmental Associates, 1975, pp. 156-158. Low multiplier effects are the rule rather than the exception in rural areas. See Summers, Gene F., *et al.* *Industrial Invasion of Nonmetropolitan America.* New York, N.Y.: Praeger, 1976, pp. 54-59. Population employee multipliers used were 2.05 for construction workers, 2.50 for operation workers, and 2.0 for service workers (all of which take into account two-worker households). They were adapted from Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

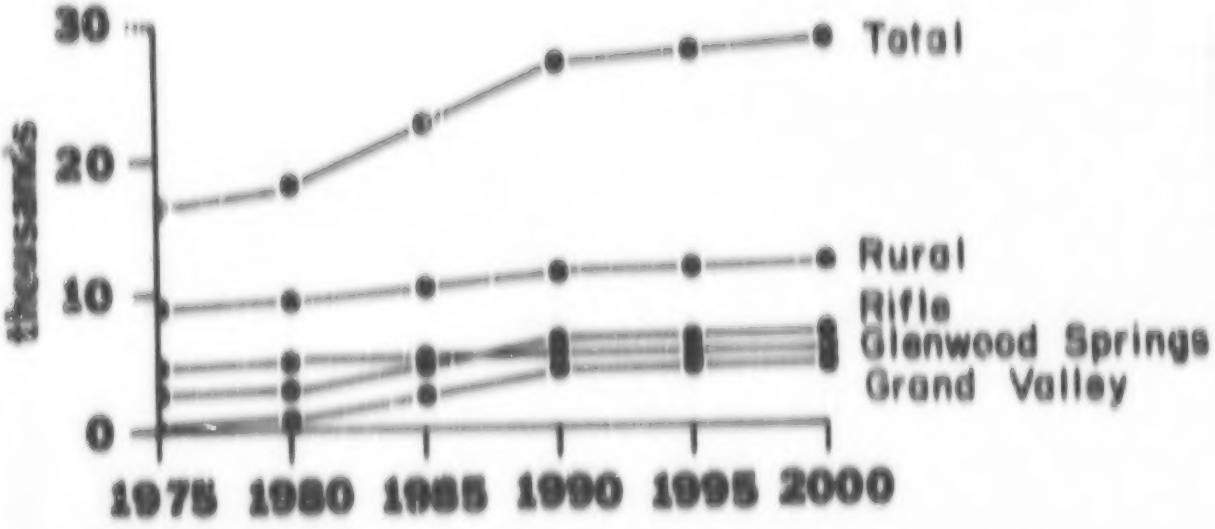

FIGURE 8-6: POPULATION ESTIMATES FOR GARFIELD COUNTY, 1980-2000

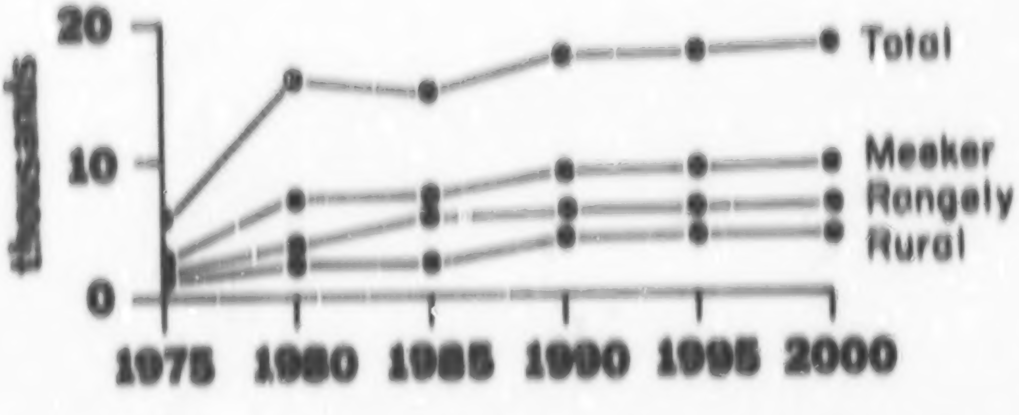

FIGURE 8-7: POPULATION ESTIMATES FOR RIO BLANCO COUNTY, 1980-2000

TABLE 8-37: POPULATION ESTIMATES FOR GARFIELD AND RIO BLANCO COUNTIES AND GRAND JUNCTION, 1975-2000[a]

County	1975	1980	1985	1990	1995	2000
Rio Blanco						
Meeker	2,200	7,000	7,100	8,800	9,000	9,300
Rangely	1,800	6,850	5,600	5,800	6,000	6,100
Rural	1,200	2,050	2,150	3,800	3,800	3,900
Total	5,200	15,900	14,850	17,400	17,800	18,300
Garfield						
Rifle	2,500	2,950	4,800	6,400	6,550	6,700
Grand Valley	350	700	2,350	4,200	4,300	4,400
Glenwood Springs	4,650	4,850	5,050	5,250	5,400	5,550
Rural	8,900	9,500	10,400	11,350	11,650	11,950
Total	16,500	18,000	22,600	27,200	27,900	28,600
Grand Junction Area Total	45,000	49,200	54,100	59,500	62,600	65,700

[a]Estimates incorporate an annual natural increase of 0.8 percent through 1990, and 0.5 percent thereafter, except in Grand Junction where the rates used were 1.5 percent and 1.0 percent to include urban agglomeration effects. In general, given the conditions assumed in this scenario, the estimates should have a maximum error range of ±25 percent. For example, an estimate of 6,000 people should be interpreted as between 4,500 and 7,500. These ranges carry through the subsequent analyses based on population estimates.

Grand Valley vicinity at the mouth of Parachute Creek is expected to receive a large amount of the increase in population, although a new town is not anticipated in this scenario.[1]

The population of Garfield County is expected to increase more than 70 percent to almost 29,000 people by 2000. Rifle should grow nearly three-fold to 6,700, becoming larger than Glenwood Springs by 1990. Grand Valley is expected to increase from 360 to 4,400, a twelve-fold increase. Rio Blanco County is expected to grow 230 percent by 1990, with much of the growth taking place in Rangely and Meeker (Figure 8-6). Meeker is projected to increase to 9,300 people by 2000. For the two-county area, the 25,200 population increase by the year 2000 is a 162-percent change from 1975 levels.[1]

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[1] See the uncontrolled urban development pattern in THK Associates, Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 75-77.

In general, the population increase in the scenario is expected to take place primarily in and near the established towns. Outside the two-county area, service employment will increase in Grand Junction, the major service center in western Colorado. A 46-percent population increase is expected in the Grand Junction area as a result of the energy development hypothesized in this scenario.

Age-sex breakdowns of the projected populations in Garfield and Rio Blanco Counties help in predicting changes in the housing and educational needs of the area. From the basic age-sex distribution which existed in 1970, the new employment was assumed to be distributed by age as found in recent surveys in the West.[2]

The resulting age-sex distribution in Table 8-28 shows an increase in the 25-34 age group and, through 1990, the 0-5 age group. The 35-54 age group increases after 1990. In addition, the relative proportion of males to females is high during the 1980-1995 period because of single males associated with energy development.

8.4.4 Housing and School Impacts

Housing demand and school enrollment can be estimated by employing the information in Tables 8-27 and 8-28 and assuming that children in the 6-13 age group are in elementary school and those in the 14-16 age group are in secondary school (see Table 8-29 and Figure 8-8). Based on these projections, expected housing demand nearly doubles almost immediately, indicating that about 4,700 new units will be needed in the Garfield-Rio Blanco County area by 1980. Growth in demand is somewhat slower thereafter, but 3,700 additional new homes will be needed between 1980 and 2000.

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[1] For a scenario which projects greater population growth, see THK Associates, Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 75-77.

[2] Data adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

TABLE 8-28. PROJECTED AGE-SEX DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000[a]

Age	1975	1980	1985	1990	1995	2000
Female						
65-over	.055	.031	.028	.024	.028	.028
55-64	.051	.032	.029	.026	.032	.041
35-54	.113	.091	.085	.082	.104	.116
25-34	.059	.097	.096	.107	.087	.093
20-24	.033	.037	.036	.038	.045	.053
17-19	.030	.021	.033	.033	.033	.036
14-16	.031	.024	.028	.027	.030	.031
6-13	.078	.067	.080	.072	.077	.067
0- 5	.085	.052	.057	.060	.046	.025
Total	.496	.458	.472	.474	.482	.490
Male						
65-over	.050	.025	.026	.022	.024	.028
55-64	.049	.038	.031	.027	.033	.044
35-54	.116	.117	.100	.090	.120	.120
25-34	.058	.123	.123	.134	.101	.101
20-24	.031	.052	.044	.044	.051	.054
17-19	.032	.037	.035	.035	.034	.036
14-16	.034	.026	.026	.028	.030	.031
6-13	.084	.070	.082	.079	.078	.067
0- 5	.087	.053	.058	.060	.046	.025
Total	.501	.541	.528	.527	.517	.506

Source: Table 8-31 and data from Mountain West Research, Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

[a] Totals do not always sum to 1.0 because of rounding.

TABLE 8-29. NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1975-2000

Year	Number of Households	Number of Elementary School Children[a]	Number of Secondary School Children[b]
1975	6,600	3,500	1,410
1980	11,300	4,650	1,700
1985	11,300	6,100	2,150
1990	13,500	6,950	2,450
1995	13,900	7,100	2,750
2000	15,000	6,700	2,900

Source: Tables 8-31 and 2-32.

[a] Ages 6-13.

[b] Ages 14-16. These age group assumptions result in a possible underestimate of at most 25 percent (current enrollment is just over 6,700), but relative sizes are indicative of impacts.

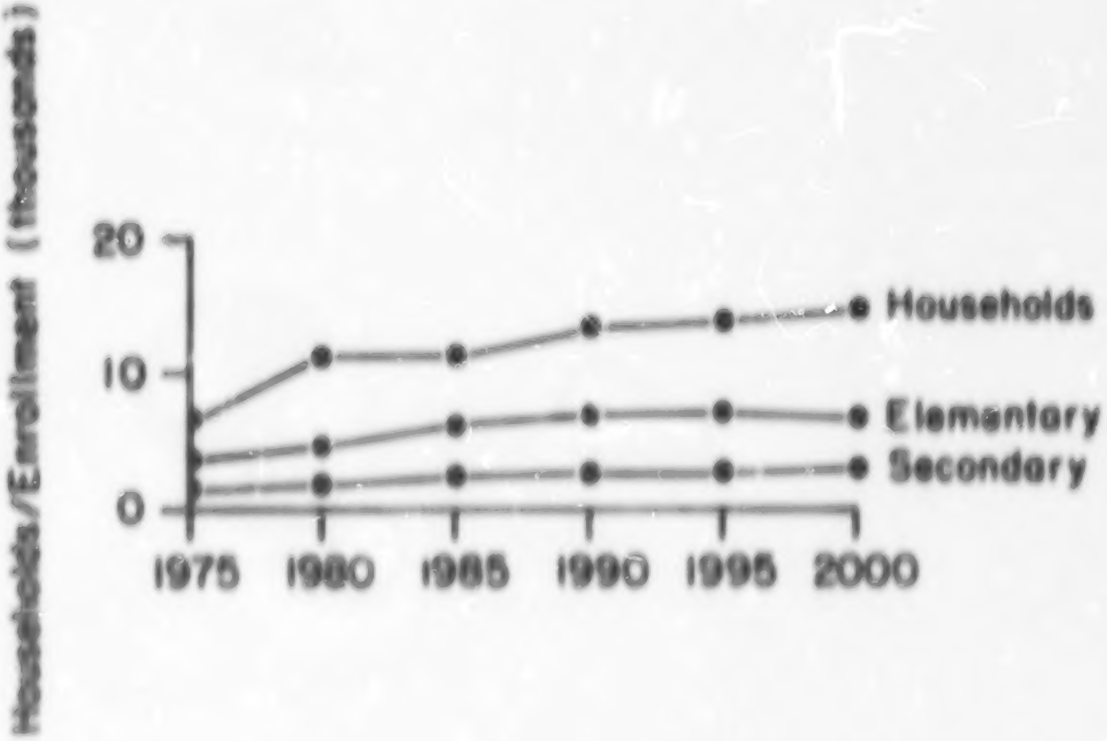

FIGURE 8-8: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1980-2000

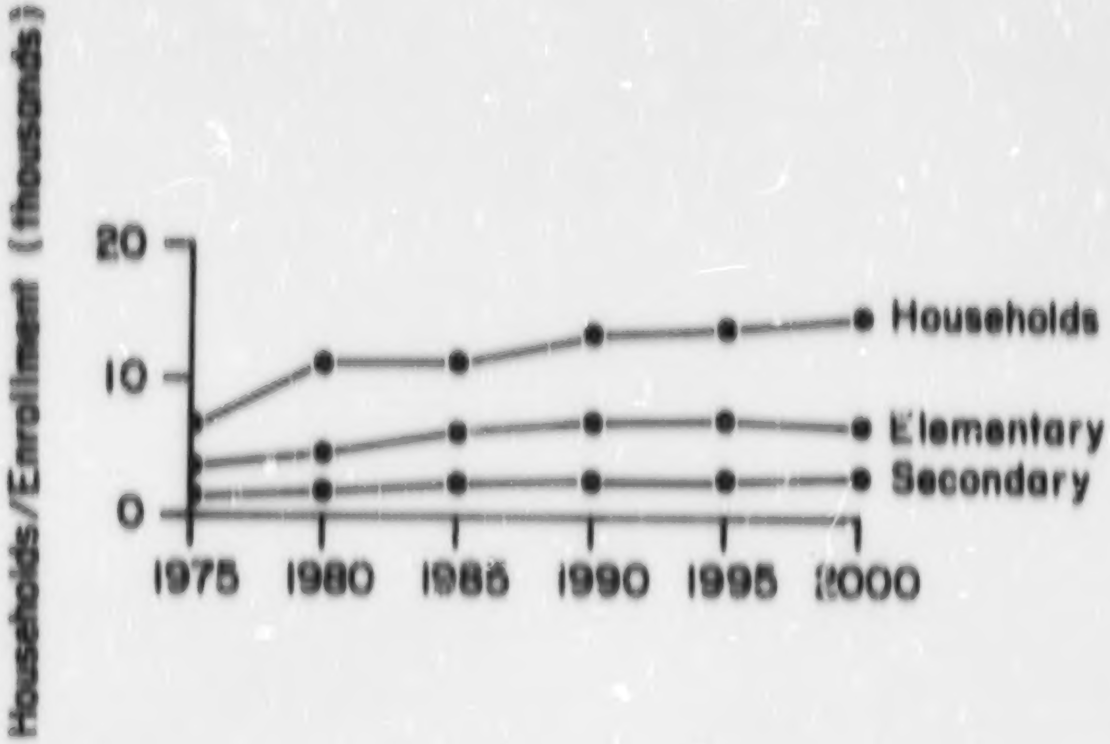

FIGURE 8-6: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1980-2000

TABLE 8-30: DISTRIBUTION OF NEW HOUSING NEEDS BY TYPE OF DWELLING[a]

Years	Mobile Home	Single Family	Multi-Family	Other[b]
1975-1980	1,900	1,900	580	320
1980-1985	-100	60	60	-20
1985-1990	600	1,250	550	-200
1990-1995	40	300	120	-60
1995-2000	110	660	330	-30

[a] Compiled from Table 8-33 and data in Mountain West Research. Construction Worker Profile, Final Report Washington, D.C.: Old West Regional Commission, 1976, p. 103.

[b] For example, campers and recreational vehicles.

The distribution of housing demand in Table 8-30 reflects the relative number of temporary construction worker households living in mobile homes through 1990, particularly between 1975 and 1980. Even more families would have to live in mobile homes if local housing construction cannot keep up. Given existing infrastructures, the majority of mobile homes will be concentrated in the Grand Valley area, where 63 of the present 87 dwellings are mobile homes. Rifle, where mobile homes currently account for less than 10 percent of available housing, is expected to maintain a relatively low percentage if the local building industry attempts to meet demands there.[1]

School enrollment impacts will vary between elementary and high school over time. Elementary enrollment is expected to peak at 7,100 in 1995 (double the 1975 level). The 380 classrooms currently available in the two-county area average 18 students, suggesting that some excess capacity is available.[2] A 32-percent rise in enrollment between 1975 and 1980 can be absorbed on an overall classroom basis, but impacts will be greater at some locations than at others (Table 8-31). For example, nearly one-half of all new enrollment by 1980 is expected in Rangely, which

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[1] Data on December, 1974 housing are taken from Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2] Ibid.

TABLE 8-31: SCHOOL DISTRICT FINANCE PROSPECTS FOR GARFIELD AND RIO BLANCO COUNTY DISTRICTS, 1975-2000
(in 1975 dollars)

Location	Year	Enrollment Increase over 1975	Classrooms at 21 per Room	Capital Expenditure Increase (Millions of Dollars)[b]	Operations Expenditure Increase (Millions of Dollars)
Rifle	1975[a]	1,500	71		2.07
	1980	240	11	0.60	0.50
	1985	900	43	2.25	1.80
	1990	1,600	76	4.00	3.20
	1995	1,700	81	4.25	3.40
	2000	1,510	72	3.78	3.02
Grand Valley	1975[a]	186	20		0.44
	1980	100	0[c]	0[c]	0.20
	1985	600	17	0.89	1.20
	1990	1,150	44	2.31	2.30
	1995	1,180	45	2.36	2.36
	2000	1,010	37	1.94	2.02
Meeker	1975[a]	693	44		1.05
	1980	1,440	56[c]	2.94[c]	2.88
	1985	1,470	59	3.10	2.94
	1990	1,980	83	4.36	3.96
	1995	2,040	86	4.52	4.08
	2000	1,780	74	3.89	3.56
Rangely	1975[a]	411	67		1.11
	1980	1,515	25[c]	1.31[c]	3.03
	1985	1,140	7	0.37	2.28
	1990	1,200	10	0.53	2.40
	1995	1,260	13	0.68	2.52
	2000	1,080	4	0.21	2.16

[a] 1975 data from Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII*. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[b] An average of $2,500 per pupil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. *Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81*. Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971, by inflating to 1975 dollars.

[c] Excess capacity of classrooms in 1975 will be filled before others are needed.

TABLE 8-32: LAND REQUIRED FOR POPULATION-RELATED DEVELOPMENT IN GARFIELD AND RIO BLANCO COUNTIES (in additional acres after 1975[a])

Category	1980	1985	1990	1995	2000
Residential					
Streets	610	787	1,145	1,200	1,260
Commercial	122	158	229	240	252
Public and Community	15	19	27	29	30
Facilities	48	49	71	74	78
Industry	61	79	115	120	126
Total (acres)	856	1,092	1,587	1,663	1,746
(square kilometers)	3.5	4.4	6.4	6.7	7
(square miles)	1.3	1.7	2.5	2.6	2.7

[a] Assumes: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; and commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

in 1974 had an average of just over six students in each of its 67 classrooms. To maintain an average of 21 pupils per classroom, 25 new classrooms will be needed by 1980, three-fourths of them in elementary schools. However, by 1985, Rangely will need only 7 of the 25 additional classrooms. In the other districts, enrollment and classroom needs increase steadily, creating a $10 million increase in operating expenditures by 2000. Teachers, bus drivers, maintenance, and supplies, as well as the purchase of new school busses, will be in addition to the construction costs. The estimates in Table 8-31 suggest that the additional enrollment during the 1980's and early 1990's may well be accommodated by split sessions or temporary facilities, keeping capital expenditures for permanent facilities to a minimum. However, this may be difficult in Rangely, where the peak enrollment in 1980 will be 15 percent above the 1995 peak.

8.4.5 Land-Use Impacts

The energy facilities involved in this scenario will occupy about 13 square miles in Garfield and southern Rio Blanco Counties (Figure 8-2). However, if the facilities are located totally or primarily on land suitable for other development (which is only a small fraction of the total area), the effect will be much greater than implied by the total area occupied. The population-related land requirements shown in Table 8-32 must use the developable land in the river valleys, which comprises only about 615 square miles in the two counties.[1] The requirements for most population-related land needs amount to only 2.7 square miles (0.44 percent of the developable land and 1.15 percent of the "most suitable" developable land) in Garfield and Rio Blanco Counties.[2]

In addition to actual occupation of certain land areas by residential, corporate, and municipal facilities, other areas can become greatly changed by the leisure time activities of residents. Hunting, hiking, and even driving requires more land when there are more people; in the Rifle area, these activities could conflict with current uses of wilderness areas.[3]

8.4.6 Economic and Fiscal Impacts

A. Economic

Agriculture now dominates the economy of Rio Blanco County (35 percent of all 1972 earnings).[4] However, as energy development proceeds, the economy will shift to mining and extraction. In Garfield County, the mixed tourism-related local economy will shift to mining and service and local government employment related to population growth. Major economic benefits will result from employment and income in the energy industries and from tax revenues of various types (Table 8-33, Figures 8-9 and 8-10). The scenario development should result in a 13-percent higher median household income, while during construction the median is 28 percent above the 1975 level[5] (see Figure 8-9). The principal

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[1] THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 61-70; see also Ashland Oil, Inc.; Shell Oil Co., Operator. Oil Shale Tract C-b: Socio-Economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program, 2 vols. n.p.: March 1976.

[2] Ratings according to THK Associates. Impact Analysis, p. 70. The development ratings therein unfortunately include currently irrigated lands as favorable for development, a conflict in use which will have to be resolved.

[3] This line of reasoning is expanded in Section 8.5 Ecological Impacts.

[4] U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

[5] These income impacts will be in addition to national trends in income growth from productivity gains and other causes.

TABLE 8-33: PROJECTED INCOME DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000

	Annual Income (1975 dollars)								
Year	Less than 4,000	4,000 to 6,000	6,000 to 8,000	8,000 to 10,000	10,000 to 12,500	12,000 to 15,000	15,000 to 25,000	25,000 and over	Median Household Income
1975	.139	.078	.083	.089	.093	.119	.285	.114	12,450
1980	.090	.055	.055	.072	.074	.119	.388	.128	15,900
1985	.105	.066	.066	.091	.089	.131	.365	.096	13,900
1990	.100	.065	.063	.091	.094	.132	.372	.091	13,980
1995	.098	.065	.061	.089	.096	.132	.375	.092	14,070
2000	.098	.065	.061	.089	.096	.132	.375	.092	14,070

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, p. 22, and inflated to 1975 dollars. Income distribution for construction workers, operation workers, and service workers are from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that new service workers households have the same income distribution as long time residents and the "other newcomers" are operation employees.

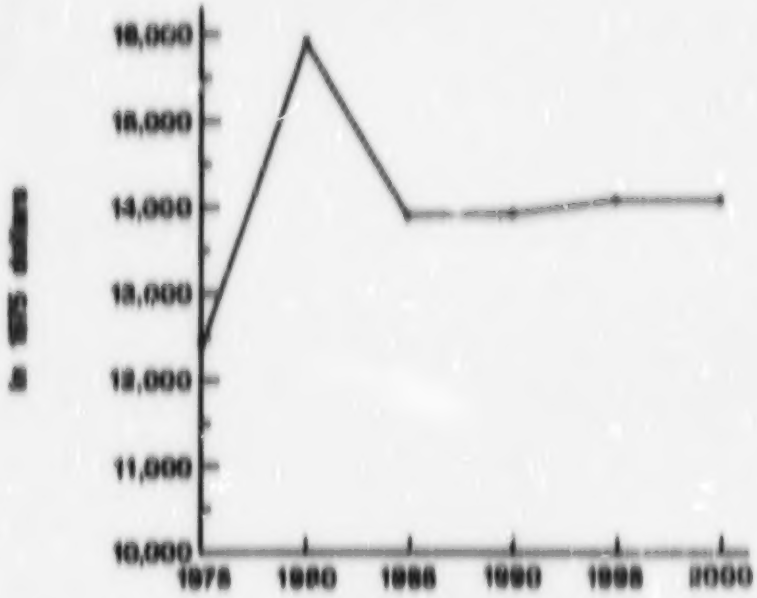

FIGURE 8-9: MEDIAN FAMILY INCOME, GARFIELD AND RIO BLANCO COUNTIES, 1975-2000

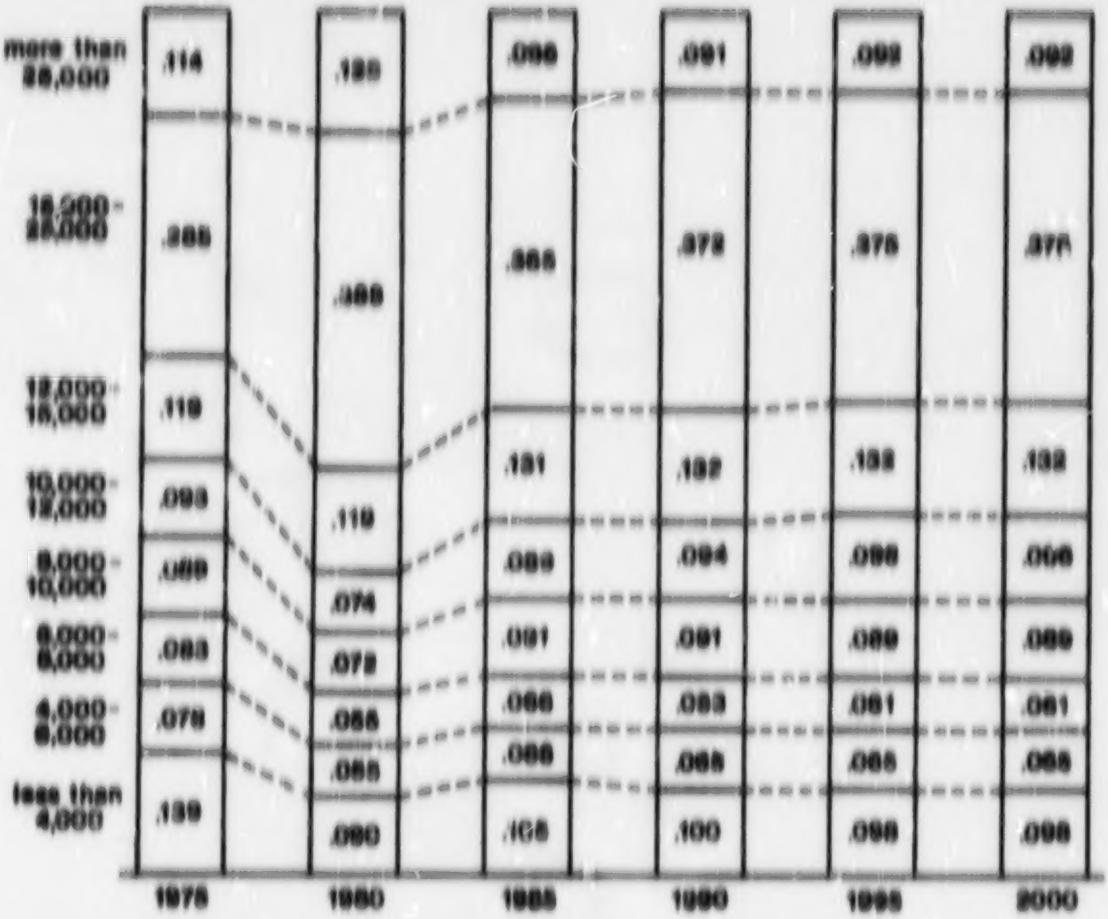

FIGURE 8-10: PROJECTED INCOME DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000 (in 1975 dollars)

change in the overall income distribution is an increase in the relative number of households earning $15,000 to $25,000 (Figure 8-10).

The general increase in business activity should be roughly proportional to the population gains in each locality. The temporary benefits from construction workers and their somewhat higher incomes will accrue primarily to the nearby towns of Rifle, Meeker, Rangely, and Grand Valley. Some commercial growth should occur in Grand Junction as a result of the Rifle-Meeker area development, but other development in western Colorado is likely to be a bigger source of growth in that city.

Local governments will receive tax benefits, although municipal services will experience shortfalls early in the period. School districts will have little difficulty after the early rush of new residents, partly because their taxing areas include the energy facilities with their relatively large valuations. Based on an enrollment increase of 6,350 students in all districts within two counties by 2000, nearly $16 million in new school construction will be required in the area. Property tax receipts should keep up with this need. In municipalities, where energy facilities do not add directly to tax revenues, meeting needs for public facilities may be more difficult.

Water and sewage treatment facilities are among the primary problems faced by any small community experiencing a significant population influx. In terms of capital expenditures, these two items will account for 75 percent of all non-school expenditures needed to serve additional population in the scenario area.[1] Within the area, excess capacity exists only in Grand Junction's water and sewage treatment facilities,[2] suggesting that the communities in Garfield and Rio Blanco Counties will be forced to expand their systems before the population arrives (1975-1980, Table 8-34) or have insufficient capacities during construction booms. Other capital needs, especially health care, will demand sizable capital outlays by 1980. Only Rangely faces a lower population when construction declines after 1980.

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[1] THK Associates. *Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study*. Denver, Colo.: THK Associates, 1974, p. 30; see also Lindauer, R.L. *Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments*. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

[2] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII*. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

TABLE 8-34: PROJECTED NEW CAPITAL EXPENDITURE REQUIRED FOR PUBLIC SERVICES IN GARFIELD AND RIO BLANCO COUNTY COMMUNITIES, 1975-2000
(in thousands of 1975 dollars)

County	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
Rifle					
Water and sewage[a]	792	3,256	2,816	264	264
Other[b]	266	1,093	946	88	88
Grand Valley					
Water and sewage	598	2,904	3,256	176	176
Other	201	975	1,093	59	59
Glenwood Springs					
Water and sewage	352	352	352	264	264
Other	118	118	118	88	88
Meeker					
Water and sewage	8,448	176	2,992	352	528
Other	2,837	59	1,005	118	177
Rangely					
Water and sewage	8,888	-2,200	352	352	176
Other	2,985	-739	118	118	59

[a] Water and sewage treatment plant requirements amount to $1,760,000 for each 1000 additional population; an additional $591,000 goes to other physical plant needs. See THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars.

[b] Other includes parks and recreation (32 percent), hospitals (45 percent), libraries (5 percent) fire protection (5 percent), policy (3 percent), administration (3 percent), and public works (7 percent). Streets and roads are not included.

TABLE 8-35: ADDITIONAL OPERATING EXPENDITURES FOR MUNICIPAL GOVERNMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1980-2000 (above 1975 levels in thousands of dollars)[a]

Year	Rifle	Grand Valley	Glenwood Springs	Meeker	Rangely
Current Base (1975) Budget[b]	800	84	1,170	361	563
1980	54	41	24	576	606
1985	276	239	48	588	456
1990	468	461	72	792	480
1995	486	473	90	816	504
2000	504	484	108	852	516

[a] Based on an average of $120 per capita (1975 dollars) broken down as follows: highways (25 percent), health and hospitals (14 percent), policy (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), administration (10 percent). See THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 41

[b] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

In terms of overall expenditures, per-capita costs tend to rise as a town's population increases because more services are provided; however, much of the increase is normally for capital expenditures and debt service.[1] Based on an average of $120 per capita, the additional operating expenditures required of municipal governments in the scenario area are shown in Table 8-35. Meeker and Grand Valley will need three and five times, respectively, their 1974 annual budgets by 1990. Particular needs likely to be generated by population growth are full-time fire protection to assist existing volunteer departments and an expansion of county sheriff and municipal police forces and vehicles.[2]

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[1] THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 41.

[2] Ashland Oil, Inc.; Shell Oil Co., Operator. Oil Shale Tract C-b: Socio-Economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program. n.p.: March 1976, Vol. 1, pp. VIII-34 to VIII-35.

TABLE 8-36: MILL LEVIES AND PER-CAPITA TAXES FOR JURISDICTIONS IN THE RIFLE AREA

Jurisdiction	Rio Blanco County[a]	Garfield County[b]	Grand Junction (Mesa County)
County assessed value for residential and commercial property per capita	$4,260	$4,410	$3,090
School mill levy	29.07	54.98	70.93
General fund mill levy	11.88	22.83	29.88
School tax per capita	124	242	219
General fund tax per capita	51	101	92

[a] 1974 tax inflated to 1975. Source: VTN Colorado, Inc. *Environmental Impact Assessment for the Proposed Colowyo Mine, Colowyo Coal Company*. Denver, Colo.: VTN Colorado, 1975, p. IV, 91-93.

[b] 1972 tax inflated to 1975. Source: Bassett, F.B. *Upper Colorado Mainstem Region, Social-Economic Profile; Grand Junction District (Colorado)*. Boulder, Colo.: Western Interstate Commission for Higher Education, 1973.

The towns in western Colorado may not be able to avoid some of the usual boom town problems.[1] An additional likely impact will be felt in tourism and recreation in the area. As described in Section 8.5, a large ecological impact from the increased population could decrease game or change its distribution. An increase in the number of hunters and habitat fragmentation would probably reduce herd sizes, creating a decrease in hunter days in the long term.

B. Fiscal

The major source of revenue from energy development will be the property tax on energy facilities. Nearly $2.7 billion will be invested in energy facilities by 1990.[2] Assuming that current mill levies are maintained, the property tax on these facilities will generate $46 million in new revenues annually by 1990. Table 8-36 details these levies, and Table 8-37 shows the

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[1] See, for example, Gilmore, John S. "Boom Towns May Hinder Energy Resource Development." *Science*, Vol. 191 (February 13, 1976), pp. 535-40.

[2] All figures are in 1975 dollars.

TABLE 8-37: PROPERTY TAX REVENUES FROM ENERGY FACILITIES
(in millions of 1975 dollars)

Jurisdiction	1978	1980	1983	1985	1990
Rio Blanco schools	2.4	5	14	18.2	18.2
Rio Blanco general	1	2	5.7	7.5	7.5
Garfield schools	0	0	0	.6	14.3
Garfield general	0	0	0	.2	5.9
Total	3.4	7	19.7	26.5	45.9

Source: Table 8-35 and Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975.

resulting revenues by jurisdiction. Valuations are based on investment costs in the Bechtel Energy Supply Planning Model.[1]

In comparison to the industrial plants, valuations of related residential and commercial property are negligible, adding only about 1 percent to the above figures. However, for some jurisdictions (such as Grand Junction), residential and commercial development will be the only source of new property taxes.

The averages in Table 8-36 can be applied to population increments in the impacted areas. At the same time, it is convenient to add another population-related source: fees for services such as water and sewer. If Grand Junction data are indicative of the entire area, $61.60 per year per capita in fees may be added to the tax revenues. Applying these rates to the anticipated population increases, revenues may be estimated for the jurisdictions in the region (Table 8-38).

Next to the property tax, the biggest local revenue will come from sharing federal mineral revenues because the hypothetical oil shale mine is located on leased federal land. The royalty rate is $0.12 per ton (1974 dollars) for shale containing 30 gallons of shale oil per ton and may be adjusted to reflect changes in the price of crude.[2] For a 100,000-bbl/day (barrels per day) facility, annual payments would be $342,000. Also, the

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[1] Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975.

[2] "Fact Sheet" accompanying Department of the Interior news release of November 29, 1973.

TABLE 8-38: REVENUES FROM RESIDENTIAL AND COMMERCIAL PROPERTY TAXES AND MUNICIPAL UTILITY FEES, SELECTED JURISDICTIONS
(millions of 1975 dollars)

Jurisdiction	1978	1980	1983	1985	1990
Rio Blanco schools	.52	1.33	1.49	1.20	1.51
Rio Blanco general	.47	1.21	1.36	1.09	1.38
Garfield schools	.10	.36	1.36	1.48	2.59
Garfield general	.07	.24	.91	.99	1.74
Grand Junction schools	.51	.92	1.62	1.99	3.18
Grand Junction general	.36	.65	1.14	1.40	2.23

Source: Tables 8-27 and 8-36.

bonus bid payment will add a much larger amount to this. The highest bonus bid so far received is the $41,300 per acre offer, obtained from the Standard Oil of Indiana/Gulf venture in 1974.[1] Assuming this to be indicative of what could be collected from a commercially viable project and applying it to the 1,820-acre mine site, the projected bonus bid is $84 million, which is payable in five annual installments starting with the bid date. (The following allocations assume bid dates of 1979 for the 50,000-bbl/day mine and 1984 for the 100,000-bbl/day mine.) Recently passed legislation allocates one-half of federal mineral revenues to the state of origin, with one-fourth of that amount intended for mitigating local impacts. Altogether, the state share would be $4.3 million per year during 1979-1983, $8.6 million during 1984-1988, and about $250,000 annually for the remainder of the mines' lives.

State income and sales taxes are the major sources of revenue tied to personal income. Colorado's income tax, which reaches 8 percent of taxable income for incomes above $10,000,[2] implies collections of $848 per household based on the projected 1980 income distribution and $794 per household based on the

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[1] U.S., Federal Energy Administration. Project Independence Blueprint Final Task Force Report: Potential Future Role of Oil Shale: Prospects and Constraints. Washington, D.C.: Government Printing Office, 1974, Appendix B, p. 17.

[2] U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Table 435. We assume a standard deduction of $4,000 per household.

TABLE 8-39: NEW SALES TAX REVENUES[a]
(millions of 1975 dollars)

Jurisdiction[b]	1978	1980	1983	1985	1990
State of Colorado (3%)	.58	1.69	2.02	1.74	2.65
Rio Blanco County (0.5%)	.06	.18	.13	.11	.14
City of Grand Junction (0.5%)	.02	.07	.12	.10	.17
Total	.66	1.94	2.27	1.95	2.96

[a] Assuming 56 percent of income goes to retail sales. Revenues geographically distributed proportionally to population

[b] These are the only jurisdictions in the region which currently levy a sales tax.

steady-state distributions. Expected income tax revenues are $1.9 million in 1978, $5.4 million in 1980, $6.6 million in 1983, $5.9 million in 1985, and $8.9 million in 1990. Sales taxes are detailed in Table 8-39. Some undetermined portion of this additional revenue is overestimated because some of the immigrating workers will leave other jobs in other parts of Colorado to work on these energy projects.

Finally, all state and local revenues can be summarized by jurisdiction. These are shown in Table 8-40 and can be compared

TABLE 8-40: SUMMARY OF REVENUES DUE TO ENERGY FACILITIES
(millions of 1975 dollars)

Jurisdiction	1978	1980	1983	1985	1990
State of Colorado[a]	2.5	11.4	12.9	16.2	11.7
school districts					
Rio Blanco	2.9	6.3	15.5	19.4	19.7
Garfield	.10	.36	1.36	2.05	16.9
Grand Junction	.51	.92	1.62	1.99	3.18
County and Municipal					
Rio Blanco	1.6	3.4	7.2	8.7	9
Garfield	.07	.24	.91	1.23	7.6
Grand Junction	.38	.72	1.26	1.50	2.40

[a] Including portions of royalties earmarked for local assistance.

with anticipated expenditures for these jurisdictions. It is immediately apparent that school districts in Rio Blanco County will derive substantial fiscal advantages from the projected developments.[1] For example, in 1990, new operating expenditures in Meeker and Rangely will be at a rate of $6.4 million per year, while new revenues for these districts total $19.7 million. Mill levies could be reduced and capital requirements still be met on a pay-as-you-go basis. Garfield County districts will also enjoy surpluses eventually but may face deficits before the large oil shale facility comes on-line in 1990. (The oil shale facility is the only energy facility located in Garfield County in this scenario.) In 1985, the Rifle and Grand Valley districts will need an additional $3 million over current operating budgets, while new revenues only reach $2.05 million. Further, $2.25 million in new facilities will be needed by that date. The prospect of $16.9 million per year in new revenues after 1990 may provide a basis for borrowing in the interim.[2] County and municipal governments in these counties show fiscal patterns similar to the school districts. Grand Junction (in Mesa County) occupies an intermediate position, with moderate revenue increases ($1.50 million by 1985, $2.40 million by 1990).

If Colorado state government maintains its current rate of expenditures ($1,125 per capita), and if no more than one-fourth of the people new to this area come from out of state, then the state government will experience positive fiscal benefits. Any immigration rate much greater than 25 percent would lead to new expenses exceeding new revenues.

8.4.7 Social and Cultural Impacts

The primary societal effects of energy resource development in western Colorado should be related to the economic changes in the area. Shifts from an agricultural and tourism base to a resource-extraction base will alter the political base and social relations of the population over the long term. Conflicts between newcomers and long-time residents is most likely in Rio Blanco County where newcomers will outnumber oldtimers before 1980. Other conflicts between these groups of residents are likely, at least in the short term, because of the strain put on local services by the population increase.[1] A large cluster of mobile homes may prove to be undesirable to both inhabitants and close neighbors. Finally, the cost of living generally rises faster than the incomes of long-time residents; this is especially true for persons on fixed incomes who comprise a significant proportion of the present population. However, in general, social impacts in the Rifle area will probably be less severe than was thought a few years ago.[2]

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[1] Compare Table 8-40 with Table 8-31.

[2] Note that some of the state government's royalty share is earmarked for local impact mitigation.

The quality of life as perceived by people in the Rifle area would undergo some changes because of energy development. The present residents like the small community size and environmental quality of the area but, some are dissatisfied with the range of shopping and entertainment facilities.[3] Thus, the population growth expected with energy development, especially during the construction phase, will have a negative effect on the area's quality of life for some residents, but others will welcome the accompanying increase in the number and range of goods and services available locally. For example, educational services for adults are likely to be expanded by Colorado Northwestern Community College in Rangely. Rangely and Meeker will be most impacted by 1980 (in this scenario), after which a new stability will be difficult to achieve until after 1990. The shift in the economic base from agriculture and tourism will be indicative of the shifts in lifestyles for people in the area as more seasonally stable industries replace the dependence on the traditional lines of work.

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[1] A particular problem in rapid growth communities is a degeneration of telephone service, suggesting that private industry also has a lead time problem in coping with new demands from growth. See U.S., Federal Energy Administration. *Project Independence Blueprint Final Task Force Report; Potential Future Role of Oil Shale: Prospects and Constraints*. Washington, D.C.: Government Printing Office, 1974, p. 246.

[2] Compare FEA. *PIB Report: Oil Shale*. Pp. 238-258; and University of Denver, Research Institute; Resource Planning Associates; and Socioeconomic Associates. *Socioeconomic and Secondary Environmental Impacts of Western Energy Resource Development*. Working Paper, for the U.S. Council on Environmental Quality. Denver, Colo.: University of Denver Research Institute, 1976, pp. VII-1 to VII-11.

[3] Bickert, Carl von E. *Attitudes and Opinions Related to the Development of an Oil Shale Industry*. For the Oil Shale Regional Planning Commission and the Colorado West Area Council of Governments. Denver, Colo.: Bickert, Browne and Coddington and Associates, Inc., 1973.

8.4.8 Political and Governmental Impacts

As shown in the preceding analysis, energy development in Garfield and Rio Blanco Counties will lead to demands for new public facilities and services. Communities in the two counties will be forced to expand their water and sewer systems before the population arrives; capital will be needed for health care facilities; and fire and police protection will have to expand. Each of these demands requires increasing government activity and expenditures at the local level. However, a major problem for the communities is their lack of planning resources and infrastructure to prepare for and manage rapid population growth. This lack, together with the anticipated expenditure needs discussed above, suggests that fiscal and planning shortfalls are likely.

Although school districts and the two counties will enjoy long-term revenue benefits from the projected development, the Garfield County districts will face deficits before the energy facilities are assessed and placed on the tax rolls. That is, front-end financial problems and the manner in which revenues are distributed from both the state and the counties will greatly influence the net fiscal status of the localities and districts during the short-term construction period, especially those outside the immediate vicinity of a mining activity. The creation of a new town or planned subdivisions financed largely by industry near Grand Valley could alleviate many of the problems anticipated for that community. Rifle and Meeker will be able to handle the impact to a greater extent primarily because of their expected growth as service centers. The service-related growth of these two municipalities will help to balance the population pressure in western Colorado and will provide the towns additional tax revenues to finance capital improvements and public services.

Another impact category which will involve government is the demand for housing and mobile home subdivisions to accommodate temporary and longer term workers. Colorado provides minimum standards for subdivision design, platting, provision of utilities, open space, and similar control criteria. The Department of Local Affairs within the state's Division of Housing serves as the administrative organization to assist in the establishment and financing of needed housing. In addition, Colorado's Housing Finance Corporation can help alleviate low and middle income housing needs by securing home mortgage money for traditional lending institutions in rural areas. Since a number of the energy-impacted communities must rely on mobile homes to meet temporary population growth, it is significant that Colorado has adopted mobile home construction standards for all mobile homes sold in the state. Of more critical concern, however, is the need to assure adequate enforcement of construction standards and the provision of now non-existent mobile home park codes or design criteria.

The most important political impacts are related to land use in the area and the effect of energy development on ranchers. Politically, the rancher-dominated system will be strained by newcomers almost from the beginning of construction. As development progresses, urban centers will acquire a larger proportion of voters and, hence, political influence in the counties. This shift can begin as early as 1980 in Rio Blanco County when a large number of new permanent workers and their families are present. These potential political effects will be studied in more detail during the remainder of the study.

8.4.9 Summary of Significant Social, Economic, and Political Impacts

The Rifle scenario energy development will increase the population of western Colorado by 46,000 people, 17,000 of whom will be in the area by 1980. The early increase, consisting largely of construction workers, will require 4,700 homes, at least 40 percent of which may be mobile homes. As construction workers are replaced by operational employees, the proportion of mobile homes should decline to about 13 percent of total housing. School enrollment will increase through 1995 and subside after that. The long-term capital need for education will be about $11-14 million by 1990; operating expenditures will more than triple for the school districts serving Rifle and Grand Valley. The towns of Meeker, Rangely, Rifle, and Grand Valley likewise will receive the bulk of the population impact from development.

The long-term income benefit to Rifle area residents is estimated to be about a 13-percent increase; during construction the increase will be up to 28 percent. Some local inflation will reduce the latter to the long-term level. Grand Junction, the economic service center for the area, also will receive some commercial benefits from these energy developments.

Local governments will require greatly expanded facilities to serve the local population increases, especially in water and sewage treatment. In fact, about $19 million will be needed primarily by Meeker and Rangely by 1980; an additional $12 million will be needed by Rifle and Grand Valley by 1990. Construction for other services will require about $10 million by 1990 in the two counties.

The change from an agricultural and tourism base to an energy development base will have social as well as economic effects. Population concentrations and conflicts over agricultural land in population expansion areas will require adjustments within the local area. The overall planning capacity of local governments appears to be inadequate to manage growth in the area.

8.5 ECOLOGICAL IMPACTS

8.5.1 Introduction

The area considered for ecological impacts in the Rifle scenario extends from the Colorado-Utah state line eastward to the middle of the White River National Forest, and from Grand Mesa on the south to the northern Moffat County line.[1]

The complex topography of the area varies from river valleys at 4,700 feet to mountains higher than 11,000 feet. Both rainfall and temperature vary with topography; conditions are relatively drier and warmer at lower altitudes than at higher altitudes. The structures of the area's varied soils reflect the combined influence of biological conditions, weather, and topography. In the study area, the principal influences controlling the development of biological communities are slope, elevation, and exposure. Forestry, agriculture, and grazing have a locally important influence.

8.5.2 Existing Biological Conditions

Vegetation types correspond approximately to altitude and exposure. The major types in order of elevation are: riparian (streamside) and agricultural bottomlands; salt desert shrub; sagebrush communities; pinyon-juniper woodland, mixed mountain brush areas; mid-elevation coniferous forest; and subalpine coniferous forest. Mixtures of types are often found together in patches. The dominant species characteristic of these biological communities are summarized in Table 8-41.

Although widely distributed, most smaller animals generally live within a single community. However, some birds and most big game species range more widely. Deer mice are abundant at almost all elevations. The larger mammals (such as deer, elk, bear, and mountain lions) generally move freely between zones but use them selectively and during different seasons. Fifty-four species of mammals, 260 species of birds, and 13 species of reptiles and amphibians have been reported for the area. Rare or endangered terrestrial species include the bald eagle, and peregrine falcon; the black-footed ferret may also be present.

Aquatic habitats vary from temporary creeks and small permanent streams such as Parachute and Piceance Creeks to the area's two major rivers, the Colorado and the White. Both

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[1] A large area was considered due to the extensive influence of increased human populations.

TABLE 8-41: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, RIFLE SCENARIO

Community Type	Characteristic Plants	Characteristic Animals
Riparian (bottomlands)	Crops Cottonwood Box elder Willow species Green ash	Muskrat Raccoon Snakes (e.g., common garter) Amphibians (e.g., tiger salamander Songbirds (e.g., yellow-throat)
Salt desert shrub	Cropland (some irrigated) Shadscale Greasewood Fourwing saltbush Nuttall saltbush	Lizards (e.g., short-horned) Kangaroo rat Jackrabbit Gray fox
Sagebrush	Big sage Silver sage Rabbitbrush Bitterbrush	Antelope Mule deer (winter) Blue and sage grouse Sagebrush lizard Brewers blackbird Sage sparrow
Pinyon-juniper	Pinyon pine Utah juniper Bitterbrush Mountain mahogany Rabbitbrush	Blue and sage grouse Mountain cottontail Scrub jay Least chipmunk Mule deer Elk (winter)
Mountain brush	Serviceberry Mountain mahogany Chokecherry Snowberry Gambel oak	Deer (migratory or winter) Chickadees Kinglets Gray jay, Steller's jay
Mid-elevation	Ponderosa pine Douglas fir Snowberry Mountain maple Serviceberry	Mule deer (summer) Elk (summer) Red squirrel Lewis' woodpecker Snowshoe hare Hawks and owls
Sub-alpine forest	Engelmann spruce Lodgepole pine Aspen Fescue species Needle grass	Mule deer (summer) Elk (summer) Mountain goat Bighorn sheep Red fox Hawks and owls Clark's nutcracker

cold-water and warm-water fishes inhabit these streams, including trout, mountain whitefish, bluehead sucker, channel catfish, Colorado squawfish and carp.

8.5.3 Major Factors Producing Impacts

During the 1975-1980 time period of this hypothetical scenario, a 1,000-MWe (megawatts-electric) power plant will be built east of Meeker. This plant and its associated coal mine will remove a total of 830 acres of vegetation; transmission lines (to the vicinity of the oil shale facilities) will alter another 750 acres. Table 8-42 summarizes vegetation loss for this and the succeeding decade.

Water withdrawn from the White River at a rate of 13.1-19.4 cubic feet per second (cfs) will supply the power plant. The human population is expected to grow by 16,400 people, an increase of 25 percent, requiring an additional withdrawal of 1.3 cfs from the Colorado River and roughly 2.0 cfs from the White River.[1] Non-urban populations are expected to use groundwater (Section 6.3).

During the 1980-1990 decade, two oil shale mines and retorting plants will come on-line, and the plant sites, mine surface facilities, and spent shale disposal areas will occupy 4,570 acres. Product pipelines will affect roughly 450 acres. Roads in the area will be upgraded, especially those extending up the

TABLE 8-42: VEGETATION LOSSES;[a] RIFLE SCENARIO
(acres)

Community Type	1975-1980	1980-1990	Cumulative Total
Mountain brush	1,420	1,540	2,960
Sagebrush	110	170	280
Pinyon-juniper	50	3,240	3,290
Salt desert shrub		70	70
Riparian and agricultural		710	710
Total	1,580	5,730	7,310

[a] Includes temporary losses for transmission lines, since revegetation of rights-of-way will not restore the original habitat.

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[1] This calculation is based on distribution of urban populations by watershed, assuming a yearly demand of 140 acre-ft per thousand population.

Parachute and Piceance Creek Valleys; a new road connecting Rangely with the Piceance Creek plant site is also postulated. In addition to providing access, rights-of-way from these roads will also contain water pipelines and portions of product pipelines. Together, these facilities will occupy approximately 710 acres, of which about half are already cleared. A planned road connecting the town of Rangely to the Piceance Creek site will remove another 160 acres. Water for the Parachute Creek complex will be withdrawn from the Colorado River at a rate of 8.5-10.0 cfs. The Piceance Creek complex will rely on groundwater. A crude-oil field located near Rangely will occupy a total of 850 acres, mostly in scattered parcels of a quarter acre.

During the last decade of the scenario, the area's population will grow by another 8,100, bringing the cumulative increase in municipal water demand from the Colorado River to 6.9 cfs and from the White River to 2.3 cfs. No additional facilities will be built.

8.F.4 Impacts

A. Impacts to 1980

The most immediate impact of constructing the hypothetical 1,000-MWe power plant at Hecker will be the loss of the site's natural vegetation, chiefly consisting of sagebrush and mountain shrub. This area, managed by the Bureau of Land Management (BLM) is presently grazed in spring and fall by cattle and sheep and is kept stocked below its carrying capacity (based on forage production alone) to preserve wildlife and watershed values. The forage produced on the 830-acre plant site is roughly equivalent to food consumed in a year by 6-12 cows with calves, or 30-60 sheep.[1] However, since the land is not grazed all year, a large number of livestock using the area as seasonal pasture could be affected, depending on how long they remain. Grazing is not precluded on transmission line rights-of-way, and grazing values can be restored with proper reclamation practice to a level similar to that which existed before the line was built. However, during the period of construction, and until revegetation is complete, grazing will be curtailed on the roughly 750 acres of right-of-way. Forage production losses will be roughly equivalent to the yearly needs of 5-7 cows with calves, with the same seasonal provisions as applied at the plant site. Grazing would resume in several years, and electric field effects from the high voltage lines (described in Section 12.7) should not reduce yields.

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[1] Based on the carrying capacity of the land in acres per animal unit month (AUM), as furnished by the Bureau of Land Management (White River Resource Area personnel, personal communication, 1976). An AUM, a unit of forage production, is the amount of food consumed by a cow with calf, or five sheep in a month. Because of differences in food habits, the unit cannot generally be extended to wild grazing animals. Potential forage losses calculated in AUM's are independent of season. A total of 70-140 AUM's may be lost from the plant site, and a maximum of 100-140 AUM's from clearing the transmission line right-of-way.

The impacts of habitat removal on small non-game species that do not occupy large ranges will probably be localized, not affecting populations on adjacent undisturbed areas. These local losses will not adversely affect predators that use them as food.

The plant site is located within a large elk winter range. The total area affected is small--less than 0.3 percent of the total winter range unit--but human activity may cause elk to stay as much as a half mile from the construction site. The impact of these factors alone, in terms of elk populations, cannot be quantified with available data but would probably be small compared to overall herd size.

While the activities of construction workers will have negligible impacts on most non-game species outside the immediate plant site, several-fold increases in big game poaching are typically observed around large construction projects in the West.[1] For these species, the impact of illegal kills will probably be more significant with respect to areawide populations than habitat loss.[2] Other than big game animals, the only other species which are subject to local reductions by illegal shooting are large birds of prey, including hawks and eagles.

By 1980, the population of the scenario area is expected to increase by some 16,400 people. This increase, together with growing use by out-of-state visitors, will place additional demands on mountain habitats for dispersed backcountry recreational activities. Designated wilderness areas will receive especially heavy demand.[1] Recreational activities with a potential for altering wildlife distribution patterns include: camping and fishing, which tend to cause selective deterioration of delicate riparian and lakeshore habitats; off-road vehicles (ORV) use; and hiking and backpacking. Certain heavily used areas are already beginning to show visible signs of deterioration.[2]

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[1] Personal Communication, Grand Junction Field Office Staff, Colorado Division of Wildlife, 1976.

[2] Poaching has a much more severe impact than legitimate hunting in that it affects game of both sexes and occurs throughout the year. Removal of pregnant females and non-breeding young can affect the ability of the population to maintain adequate breeding stock. Legitimate hunting is regulated so as to assure the presence of enough breeding adults to regenerate the herd year after year.

Recreational opportunities offered by the White River and Grand Mesa National Forests tends to draw visitors from all over the nation. As a regional recreational focus, the scenario area receives a strong impact from the metropolitan centers along Colorado's Front Range as well as from the Western Slope. Since a large proportion of forest visitors reside outside the scenario development, it is not possible to calculate the impact of adding 16,400 people in the area's resident population. However, it can be noted that this population change will have a disproportionately large impact on National Forest use because residents will use the forests repeatedly, rather than once or twice yearly. Also, persons visiting new residents may help to swell the number of forest visitors.

Increased human presence in mountainous backcountry tends to lead to withdrawal of sensitive species away from areas of activity. Species considered sensitive to this type of disturbance include mountain lion, pine marten, bear, and elk. The diversity and abundance of small mammals and birds may be decreased on a local scale around heavily used areas. Snowmobile use, although usually concentrated in areas of deep snow avoided by migratory wildlife in winter, can be particularly stressful to big game animals.

Deer and elk normally winter at different elevations, which permits them to share the available winter habitat. Depending on the degree to which elk are disturbed in wintering areas, movement of these animals to lower elevations could bring them into direct competition with deer, which may suffer as a result. There is also some circumstantial evidence that displacement of elk by heavy recreational activity in their high-elevation summer range and calving ground may be associated with declines in overall numbers.[1] With existing controls on use, continued deterioration in habitat quality may be expected in wilderness areas.[2]

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[1] Two areas certain to be used more intensely are Snowmass/Maroon Bells and Flat Tops--the Elk Creek and Canyon Creek drainages. Three areas adjacent to Snowmass/Maroon Bells are also likely to be used extensively, particularly if they are designated as wilderness areas (a possibility which is currently being considered). Another area not classified as wilderness but also susceptible to heavy recreational use is the Grand Mesa National Forest immediately south of Rifle.

[2] For example, along the Canyon del Diablo portion of Main Elk Creek which lies in the scenario area, excessive use since 1972 has led to serious erosion problems along roads and trails. Increased fishing in Main Elk Creek has already reduced the quality of the trout fishery. Todd, J. "We're Losing the Wild in the Wilderness." Colorado Outdoors, Vol. 25 (March/ April 1976), pp. 10-11.

Recreational vehicle use of the rugged lands of the Roan Plateau and adjacent uplands may increase. Much of this region is presently accessible by road or trail, and most of this land is under BLM control which has limited personnel for adequate enforcement. Besides supporting a diverse small-vertebrate fauna, these lands constitute a major mule deer winter range; inadvertent or intentional harassment by ORV users could result indirectly in the loss of an unquantifiable number of animals.[3]

B. Impacts to 1990

The two oil shale mines and plants will come on-line between 1980 and 1990. Together, plant sites, surface facilities for the mines, and spent shale disposal areas will occupy 1,500 acres of predominantly mountain brush vegetation and 3,070 acres of what is now pinyon-juniper woodland. Product pipelines will remove roughly 70 acres of mountain brush, 170 acres of sage, 70 acres of saltbrush/greasewood vegetation, and 170 acres of pinyon-juniper. New roads will occupy a total of approximately 710 acres in the riparian/agricultural zone but will remove substantially less than that amount of vegetation (probably only about 360 acres) because the widths of the existing roads are already cleared. A new road connecting the town of Rangely to the Piceance Creek site will remove 240 acres of mixed pinyon-juniper and upland sagebrush.

The lands affected by the combined plant and mine sites and their associated support facilities are presently grazed seasonally under BLM management and are stocked at less than carrying capacity. Forage produced is equivalent to the amount consumed annually by roughly 50-60 cows with calves, or 250-300 sheep.

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[1] San Juan National Forest Staff, personal communication, 1976.

[2] The White River National Forest has no current plans to institute a backcountry permit system. Colorado Division of Wildlife Staff, personal communication, 1976.

[3] During the late winter months, deer are usually in their poorest condition. Avoiding off-road vehicle pursuit, especially by snowmobiles, may debilitate weakened individuals sufficiently to reduce their resistance to disease.

The oil field development around Rangely will disturb a total of 850 acres, divided between the oil wells themselves and the gathering pipelines connecting them. Grazing domestic animals will not be curtailed by this activity, although the total forage produced by the affected range--primarily winter sheep range kept 25-30 percent understocked--will be reduced by roughly the equivalent of the annual requirements of 3-5 cows-with-calves. Due to the seasonal use of these lands, however, carrying capacity may be reduced by more than this number of animals.

The vegetational diversity of this area provides habitat for a variety of small vertebrates. As discussed above with respect to the power plant, the loss of approximately 5,000 acres of habitat, although its local impact is high, will not threaten the stability of areawide populations. Predator populations and wintering birds of prey may be less frequent locally as their prey base declines, but areawide populations will probably remain stable.

As in the case of the power plant, the introduction of large construction forces will probably be associated with increased big game poaching. Particularly vulnerable (because of their proximity to urban concentrations) are the elk which winter in the Roan Plateau and adjacent highlands, the deer wintering in the foothills north of the Colorado River Valley and Grand Valley, and antelope in Grand Valley proper. Poaching could result in declines in all these populations by 1990. Hawks--the other main target of illegal shooting--could also be reduced in numbers, at least around urban areas. Bald eagles wintering along the White River between Meeker and the Piceance Creek, and south of Rangely, are likely to be particularly vulnerable.

The additional auto traffic in and out of the two oil shale plant/mine complexes will also have an additional adverse influence on wildlife, particularly on mule deer which concentrate in the Parachute Creek Valley during the winter. Initially, roadkills of wildlife will increase sharply. As many as 100 deer may be killed in the first year or two of heavy traffic in Parachute Creek.[1] Subsequently, deer may begin to avoid their old winter concentration areas and attempt to winter in adjacent habitats.

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[1] Colony Development Operation, Atlantic Richfield Company. *An Environmental Impact Analysis for a Shale Oil Complex at Parachute Creek, Colorado*, Part I: *Plant Complex and Service Corridor*. Denver, Colo.: Atlantic Richfield, 1974; and U.S., Department of the Interior. *Final Environmental Statement for the Prototype Oil Shale Leasing Program*, 3 vols. Washington, D.C.: Government Printing Office, 1973.

Following the opening of the Piceance Creek oil shale plant, an additional impact will arise from the depletion of groundwater withdrawn from the Green River aquifer to meet the plant's requirements. As indicated in Section 8.3.4, some hydrologists believe that 10 miles of the upper Piceance Creek, and surrounding springs and seeps, may ultimately be dewatered by aquifer depletion.[1,2] Water quality in the lower portion, lacking the normal dilution, will show increased dissolved solids. When pumping stops, the normal groundwater regime is expected to restore itself in roughly a decade.

The effect of this dewatering on vegetation will be confined primarily to the riparian and agricultural areas. Deteriorated water quality could curtail irrigation in the remainder of the drainage. This will probably result in a shift in vegetation from cultivated grasses to one of the two major native valley floor associations: sagebrush and saltbush-greasewood. Accumulation of salts in irrigated soils may favor the latter.

Some species of terrestrial animals will be affected directly by the loss of these valley vegetation types. This includes muskrat, raccoon, other stream-side mammals of medium size, and the characteristic small bird species of riparian woodlands. Small mammals, which are abundant in irrigated haylands, will be reduced in numbers, which may in turn lead to locally reduced numbers of predators and wintering birds of prey.

While the upland vegetation may persist without change, the loss of accessible water from springs and streams will probably alter the composition and perhaps the abundance of their animal communities. For example, sage grouse and blue grouse require moist areas with plentiful succulent vegetation and accessible water during the brood-rearing phase of their life cycle. A sage grouse brood-rearing area lying along the southern edge of the Piceance basin will probably be abandoned if its springs are

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[1] Dewatering the Parachute Creek aquifer will induce a similar but less extensive effect in Parachute Creek. A 55-70 percent flow reduction in Middle Fork below Davis Gulch is expected, but reduction in the flow of Parachute Creek will be only about 2.5 percent. Springs and seeps at the head of the Parachute Creek drainage will also cease flowing. U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975.

[2] Energy Research and Development Administration. Personnel at the Laramie Research Center believe that these estimates of stream dewatering are excessive. Personal communication, December 1976.

lost. In winter, mule deer can probably obtain their water needs from snow or meltwater; thus, the large populations wintering there might not be seriously affected by groundwater depletion. However, deer may cease to use some of the area in summer.

Cumulative water demands on the White River will reduce flows 22-30 cfs between Meeker and the mouth of Piceance Creek. This loss amounts to a negligible percentage of the river's average flow of 609 cfs below Meeker. During periods of low flow (July through August), total discharge may be reduced by roughly 7 percent during an average year and by as much as 18 percent during exceptionally dry years.[1]

Reduced flows may result in slight increases in salinity downstream. Due to dewatering, the sport fishery in the Piceance Creek, which includes brown, rainbow, and brook trout and mountain whitefish, will probably be lost or degraded. More adaptable, non-game species may remain.

The potential ecological impact of flow reduction in the White River is impossible to quantify with available data. Flow-reduction sufficient to result in ecological stress is not likely to occur every year. In-stream flow needs for maintaining the aquatic community have not been established for the White River. Lowered current velocity will reduce populations of organisms living on sediment-free stream bottoms fed on by fish and limit fish spawning or nesting habitat.

The two oil shale complexes will dispose of spent shale in on-site impoundments; catastropic failures of these impoundments are unlikely during the 30 years of plant operation.[2] However, should such an event occur (most probably as a result of a flash flood), spent shale from the Parachute Creek disposal pile could be carried as far as the Colorado River, and Piceance shale could reach the White River. The fine-grained shale could physically obliterate existing bottom communities in Parachute Creek, rendering them unstable and reducing productivity for several years. Heavy metals in the shale could be slowly released into the aquatic environment, possibly contaminating the food chain if present in sufficient quantities. Also, there is evidence that carbonaceous spent shales of the type produced by the TOSCO II process contain at least moderately carcinogenic substances which are water soluble and subject to leaching.[1]

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[1] Period of record for the White River below Meeker does not permit estimation of the frequency of such years. A second low-discharge period occurs in January and February.

[2] U.S., Department of the Interior, Bureau of Land Management. *Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado*. Washington, D.C.: Bureau of Land Management, 1975.

Salts (such as the sulfates of sodium, potassium, calcium, and magnesium) trace elements (such as beryllium, fluorine, nickel, copper, zinc, and lead), and potentially cancer producing polynuclear aromatic hydrocarbons contained in the retorted shale piles could possibly find their way into ground and surface waters through percolation and runoff. However, this movement can be restricted by such methods as compaction of the shale, channeling of underflow or groundwater drainage, and use of catchment dams to impound seepage. When abandoned, the spent shale pile could be sealed with a bertunite clay or a similar material, covered with a blanket of inert material such as sand, and layered with topsoil before being resealed. These alternative treatments stabilize the surface, reduce leaching, and lower the chance of erosion[2] to control the movement of soluble contaminants in runoff.

The projected emissions of sulfur dioxide (SO_2) result in periodic high ground-level concentrations when plumes impact on adjacent high terrain. The highest projected 3-hour average (0.7 parts per million arising from the 100,000-bbl/day plant) is within the range causing acute damage in experiments with ponderosa pine. The sensitivities of other woody plants in the area are either lower or have not been tested. The area of vegetation damage would probably be less than 1 to 2 square miles. Ground-level concentrations near the smaller plant are not high enough to suggest such acute damage, although chronic impacts (resulting in reduced growth, vigor, and resistance to disease) cannot be ruled out. Slight to negligible soil acidification[3] could also result from a combination of dry deposition of particulate sulfates filtered out by vegetation and rainout of sulfates and SO_2. Total scenario SO_2 emissions are probably not high enough to result in acid rain problems, although acid mists could form locally under certain conditions.

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[1] Schmidt-Collerus, Josef J. *The Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations*. Denver, Colo.: University of Denver, Research Institute, 1974.

[2] Pfeffer, Fred M. *Pollutional Problems and Research Needs for an Oil Shale Industry*. EPA-660/2-74-067. Ada, Okla.: Robert S. Kerr Environmental Research Laboratory, 1974.

[3] Acidifying the soil with sulfates is thought to increase the rate at which nutrients are lost from the soil by leaching.

Alkaline shale dusts and salts carried in cooling tower drift also damage vegetation. Processed shale resembles cement-kiln dust, which is thought to cause premature needle-drop in conifers,[1] would be confined to the immediate plant and spent shale disposal areas. The effect of salt deposition around cooling towers would also be confined to an area within a few hundred yards in the direction of prevailing winds. The highest salt deposition rates will be associated with the power plant; the larger oil shale complex at Piceance Creek will have the next highest level, and the lowest level will occur at the Parachute Creek oil shale plant.

Accidental rupture of product pipelines could release quantities of oil or ammonia into the Parachute Creek drainage area. The effects of such a spill could be both acute (from introducing water-soluble toxins into the aquatic ecosystem) and chronic (from fouling of the bottom by oil).[2] Relatively small spills might res[illegible] possible fish kills.[3] Following a spill which entered one [illegible] the flowing rivers or streams in the scenario area, oil would tend to collect in the quiet backwaters used by young fish and could foul productive riffle areas.

The bulk of the human population influx into the scenario area is expected by 1990. Most changes associated with urban growth should be apparent by 1985, although they intensify somewhat later. In addition to urban growth, this increase will add to existing demands for recreational and second home sites. Areas most affected by this kind of growth will include the White River valley east of Meeker, the Glenwood Springs area, and the Rifle area.

The major impacts of urban and residential growth on animals arise through fragmentation of habitat; for example, where foothills used as winter deer range are subdivided for recreational homesites and local intensification of such activities as ORV and trail bike use and similar miscellaneous disturbances.

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[1] U.S., Department of Health, Education and Welfare, Public Health Service. Air Quality Criteria for Particulate Matter, National Air Pollution Control Administration Publication No. AP-49. Springfield, Va.: National Technical Information Service, 19[illegible]

[2] Raw shale oil also typically contains carcinogenic compounds.

[3] U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement, Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975.

Valley and foothill habitats, which contain the most developable lands, are most vulnerable to this type of deterioration.

Fragmentation of biological communities is likely to have the greatest impact in the White River valley east of Meeker, and species with large ranges will be most affected. For example, according to the Colorado Division of Wildlife personnel, 30-50 percent of the elk herd in the White River National Forest winter on private lands, and available winter range is thought to limit the size of this herd. Elk are sensitive to human disturbance and tend to move completely away from areas with increased levels of activity.[1] Therefore, the impact of energy-related habitat fragmentation and clearing will be greater than the proportion of acreage involved. Mule deer winter range will also be affected. Deer are less liable to wholesale emigration in response to habitat fragmentation, but some measurable reduction in numbers is probably inevitable.

Urban development will occur primarily in the major river valleys, and fragmentation will probably affect species typical of the cultivated valley lands. However, these species are adapted to fragmented habitat, although the chukar partridge, a bird with narrow habitat requirements, is likely to be eliminated locally near Grand Junction. This could reduce the total breeding population slightly. Beaver remaining in the valley might also suffer from clearing of riparian vegetation, which is their primary food source.

C. Impacts to 2000

No new facilities will be added during the 1990-2000 time period, although population will continue to climb, resulting in a cumulative increase of 45,900 persons areawide. The impacts described above that result from urban/residential development and increased recreational demand will continue to intensify.

The impacts of the Rifle scenario are quite complex. Table 8-41 summarizes these impacts on several selected animal species. By 2000, their cumulative effects on several species of interest to man will be as follows.

1. Game Species

While not significantly affected by any of the impacts of energy facilities, elk may experience range displacement, and

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[1] This statement represents the current conventional wisdom; recent observations at Glenwood Springs and Steamboat Springs have indicated that elk may return to such ranges after a few years (Colorado Division of Wildlife, Grand Junction, personal communication), 1976.

TABLE 8-43: FORECASTS OF STATUS OF SELECTED SPECIES

	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Continued slight decline.	Continued slight decline.
[illegible]	Little change.	Little change.	Little change.
[illegible]	Little change.	[illegible]	Continued stable or slight decline.
[illegible]	[illegible]	[illegible]	Continued stable or slight decline.
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]	Little change.	[illegible]	[illegible]
[illegible]	Little change, if present.	Little change, if present.	Little change, if present.
[illegible]	Little change.	[illegible]	
[illegible]	Little change.	Little change.	Little change.
[illegible]	Little change.	Little change.	Little change.
[illegible]			
[illegible]	Little change.	Little change.	Little change.
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

possible direct reduction in numbers, as a result of population growth. Mule deer population trends have been low and decreasing in recent years, but the reasons for this are not known with certainty. It appears reasonable to expect an accelerated decline throughout the study period. Antelope habitat in Grand Valley, already substantially fragmented by agriculture, will be further affected by urban and residential growth and probably by the use of ORV's near population centers. Coupled with poaching pressure, these influences will probably contribute to an overall decline in the antelope population throughout the scenario time frame.[1]

2. Rare and Endangered Species

Bald eagles within the scenario area have habitat classified as critical along the White River between Piceance Creek and Meeker and three small areas south of Rangley. These areas are all easily accessible from human population centers, and shooting will probably reduce the number of eagles using these areas. Slight to marked declines may be expected from about 1978 through the scenario time frame.

8.5.5 Summary of Ecological Impacts

Major ecological impacts are ranked into categories in Table 8-44. These categories are based upon the extent of community change and number of species affected. Class A impacts such as habitat removal or fragmentation or changes caused by the failure of shale piles or product are the most severe. Class B impacts locally affect fewer species and include stream flow depletion and illegal shooting. Impacts which are likely to affect the fewest animals and are extremely localized, such as the localized plant damage from plume impaction, are ranked as Class C.

A fourth category includes impacts that cannot be evaluated with certainty because adequate understanding of their mechanisms is not available. The complex processes that govern the movement of toxic metal, ions, and organic substances such as may be contained in spent shale piles are not well enough known to determine whether normal operation will involve a risk of contaminating Parachute and Piceance Creeks. Similarly, ignorance of the quantitative dynamics of acid rain formation and of the entry of atmospheric sulfates into forest soils means that the risk of subacute damage to vegetation from SO_2 emissions cannot be assessed when only the amounts of SO_2 emitted are known.

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[1] Selected additional game species are mentioned in Table 8-43.

TABLE 8-44: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

Impact Category	1975-1980	1980-1990	1990-2000
Class A		Pipeline rupture Dam failure Habitat fragmentation	Pipeline rupture Dam failure Habitat fragmentation
Class B	Illegal shooting	Flow depletion White River Illegal shooting Increased recreational use of backcountry areas	Flow depletion White River Groundwater Depletion Illegal shooting Increased recreational use of backcountry areas
Class C	Grazing losses	Grazing losses Localized SO_2 plant damage	Grazing losses Loss of irrigation water, Piceance Creek
Uncertain		Leaching of toxins from spent shale	Leaching of toxins from spent shale Subacute SO_2 injury to vegetation

SO_2 = sulfur dioxide

8.6 OVERALL SUMMARY OF IMPACTS FOR THE RIFLE SCENARIO

The developments hypothesized for the Rifle area produce benefits of 325,000-bbl/day (barrels per day) of oil and 1,000 megawatts of electricity. Most of this energy will be transported out of the Rifle area and the western region. Average incomes will increase about 13 percent over present levels, and economic service activities will be increased. As a result of increased urbanization, residents in the area will enjoy more services and amenities, and several existing communities will either acquire or improve water and sewage treatment facilities, health services, parks, and recreational areas. Communities will also be able to professionalize their staff, particularly in planning. Improved roads largely in the river and creek valleys will make access to recreational areas easier for hunters, hikers, off-road vehicle enthusiasts, and other potential users.

On the negative side, air pollution impacts in at least two categories will exceed either Colorado or federal standards. Colorado sulfur dioxide (SO_2) standards are exceeded by a factor of 10 by the 1,000-megawatts-electric power plant and a factor of 8 by the 100,000-bbl/day oil shale facility. The federal primary standard for hydrocarbons is exceeded, as fugitive emissions from the 100,000-bbl/day facility produce ambient concentrations that are 300 times the standard. There may also be an oxidant problem at Rifle and Grand Valley, visibility in the area will be reduced, and some Class II significant deterioration increments are exceeded.

Mine dewatering will lower groundwater tables so that after several decades, seeps and springs within several miles of the mine along Piceance Creek may diminish or run dry which may affect vegetation and animal populations. In the long-term, processed shale, whether stored on the surface or underground, will potentially have an impact on groundwater and surface water. Leachate from both will enter bedrock aquifers and local streams. It is also likely that, over the long-term, the waste disposal ponds at the oil shale plants and the power plant will become sources of contaminants which will infiltrate local aquifers and possibly migrate into surface streams. The use of surface water in the Rifle area will also be a significant impact. Using this water for energy development will deny it to other users.

The most serious fiscal problems are related to providing the social structure needed to serve the population increase of 45,000 people by 2000. Boom impacts will be those commonly experienced in communities and areas when rapid, intensive energy resource development takes place. Some $12-15 million in capital will be needed to meet expanded education needs; housing will be inadequate and, during construction, mobile homes will constitute as much as 40 percent of all housing in the area. As is almost always the case, local governments are initially ill-equipped to respond to rapid growth, lacking as they do both adequate professional staff assistance and the revenues required to expand existing services or to institute new ones.

Habitat removal from the new population and the energy facilities will adversely affect both large and small animals, but changes to animal population will not be large. Larger stresses to animal life are more likely from additional hunting and from reduction in stream flow, which may eliminate some aquatic species and reduce riparian habitat. Plume impaction from power plants and oil shale facility is likely to produce damage to vegetation in an area up to several square miles. Process engineering changes and the imposition of additional environmental control technologies, such as increased efficiency of SO_2 scrubbers, would lessen air impacts. Some air, water, and land impacts can be mitigated by *in situ* oil shale retorting.

CHAPTER 9

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE GILLETTE AREA

9.1 INTRODUCTION

The hypothetical development proposed in the Gillette scenario will take place in Campbell County, Wyoming (Figure 9-1). This development consists of six surface coal mines, a mine-mouth electric generation plant, two coal gasification plants, a coal liquefaction plant, coal export via both rail and slurry pipeline, natural gas production, a uranium mine, and a uranium mill.[1] As shown in Figure 9-2, all these facilities are located within 40 miles of Gillette. Although some of the electricity is to be distributed within Wyoming, most of the energy is to be transported to demand centers in the Midwest. Construction of these facilities was to have begun in 1975, and all the facilities will be in operation by the year 2000. Table 9-1 identifies the technologies to be used and gives the timetable for their deployment.

In 1974, Campbell County had a population of 12,000, which was double its 1960 total. This population influx resulted primarily from the significant energy-related employment opportunities in the area. The county's 1970 median income was $11,300, which was higher than both the Wyoming and national medians. Assessed 1975 valuation was in excess of $32 million, which was the highest in the state. At current tax rates, this valuation constitutes a tax base adequate to provide county social services for an increasing population. The county is governed by a three-member board of commissioners. Currently, all three commissioners are either ranchers or local businessmen; newcomers

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[1] While this hypothetical development may parallel actual development proposed by Carter Oil Company, Northern Natural Gas, Black Hills Power and Light, Carter Mining, Atlantic Richfield, Wyodak Resources Development, Kerr-McGee, Sunoco Energy Development, AMAX Coal, El Paso Natural Gas, Falcon Coal, Shell Oil, and others, the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

FIGURE 9-1: MAP OF THE GILLETTE SCENARIO AREA

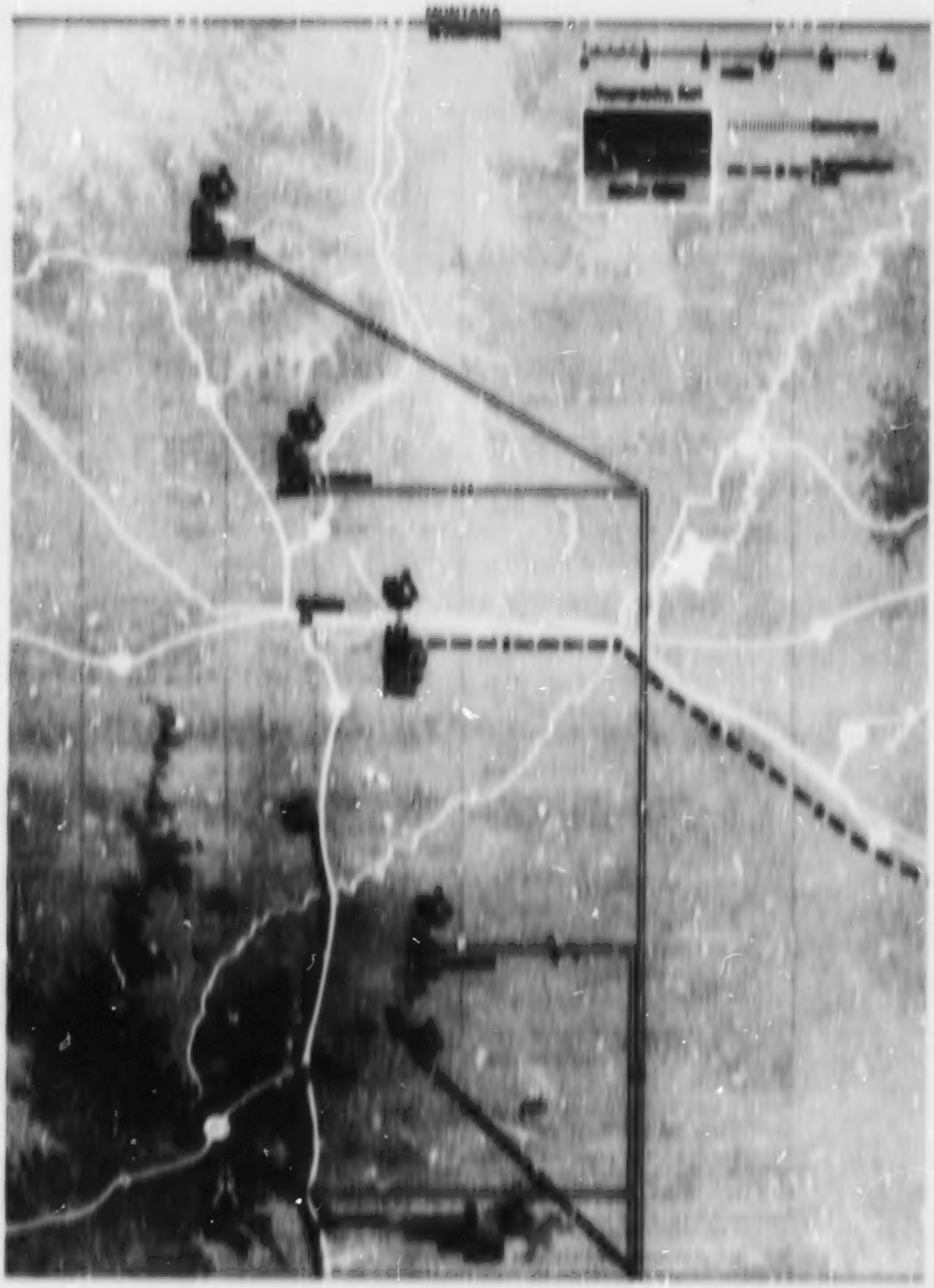

FIGURE 9-2: ENERGY FACILITIES IN THE GILLETTE SCENARIO

TABLE 9-1: RESOURCES AND HYPOTHESIZED FACILITIES AT GILLETTE

[illegible]	Characteristics			
[illegible] billions of tons [illegible]	Coal [illegible] Heat Content	[illegible]	Btu's/lb	
[illegible]	[illegible]			
[illegible]	Facility Size		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1,100	[illegible]	[illegible]	Uranium
[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1970	Natural Gas
[illegible]	[illegible]	[illegible]	[illegible]	Lurgi
[illegible]	100	[illegible]	[illegible]	Turbine Generator
	100	[illegible]	[illegible]	Turbine Generator
	1,000	[illegible]	[illegible]	Turbine Generator
[illegible]	1,000	[illegible]	[illegible]	Uranium Mill
[illegible]	[illegible]	[illegible]	[illegible]	Synthane
[illegible]	[illegible]	bbl/day	[illegible]	Synthoil
Transportation Coal [illegible] from mines to [illegible] Slurry Pipeline	[illegible]	[illegible]	[illegible]	[illegible]
Gas One [illegible]-inch pipeline	[illegible]	[illegible]	1970	Gas
Oil One [illegible]-inch pipeline	100,000	bbl/day	[illegible]	Oil
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

have not yet displaced locals as might have been expected. Although countywide zoning regulation is not practiced, development in an area around Gillette is controlled. The county helps fund Gillette's Department of Planning and Development, which is currently working on a countywide comprehensive plan.

Gillette, the county seat and the only incorporated town in Campbell County, had a population of 10,000 in 1975. It is governed by a mayor and city council. While there is no city manager, there is a part-time city administrator. The city provides public safety, water, sewer, sanitation, and electrical services. Schools are operated by a countywide system, and the city cooperates with the county to provide animal control, fire protection, an airport, and snow removal. Both the water and sewer systems are operating at capacity, and efforts are under way to expand both.

Most of the area around Gillette is still rural, and ranching is a major activity. At higher elevations, ponderosa pine and juniper woodlands predominate. At lower elevations there are deciduous woodlands along streambeds; however, most of the area is rangeland. The 4-percent decline in farmland in Campbell County from 1969 to 1974 is part of a 3-percent decline throughout Wyoming.

Runoff from the limited rainfall drains northward into the watersheds of the Powder and Belle Fourche Rivers, both of which are within the Upper Missouri River Drainage Basin. These surface waters have intermittent flow and are not a reliable and adequate supply.

Air quality in the region is good, although winter inversions offer the potential for periods of pollutant accumulation. The only existing source of industrial emissions is a small power plant located west of Gillette. Selected characteristics of the area are summarized in Table 9-2.

9.2 AIR IMPACTS

9.2.1 Existing Conditions

A. Background Pollutants

Measurements of criteria pollutant[1] concentrations in the Gillette area indicate that no federal or Wyoming standards are currently exceeded. Based on these measurements, annual average

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[1] Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, non-methane hydrocarbons, nitrogen dioxide, oxidants, particulates, and sulfur dioxide. The term "hydrocarbons" is used to refer to non-methane HC.

TABLE 9-2: SELECTED CHARACTERISTICS OF THE GILLETTE AREA

Characteristic	Value
Environment	
Elevation	4,000-5,000 feet
Precipitation	14 inches
Temperature	
Winter Daily Low (January)	11°F
Summer Daily High (July)	87°F
Air Stability	Stable 31% of the time
Soils	Sandy to sandy loam, variable
Biota	
Vegetation	Grasslands (plus coniferous and deciduous woods)
Croplands	92-percent rangeland, 4-percent croplands (forage)
Dominant Animals	Cattle, rabbits, antelope
Major Limiting Factors	Droughts, grazing
Social and Economic[a]	
Mineral Ownership (percent)	
Federal	46.8 %
State	7.1 %
Local Government and Private	46.1 %
Land Ownership	
Federal	12.6 %
State	6.5 %
Local Government and Private	80.8 %
Population (County)	12,000
Population Density	2.7 per square mile
Unemployment	2.6 %(1970)
Income (per family)	$18,500
Poverty Level (less than $3,000)	4.8 %
Government	
County	Board of County Commissioners
City (Gillette)	Mayor-Council
Taxation	Primarily property tax
Public Department Expenditures	$1.6 million (1973 Campbell County)

Source: U.S., Department of Commerce, Bureau of the Census. County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972, pp. 534-545.

[a] Campbell County, 1975 dollars.

background levels for three pollutants have been estimated in micrograms per cubic meter ($\mu g/m^3$) as: sulfur dioxide (SO_2), 18; particulates, 17; and nitrogen dioxide (NO_2), 4.[1]

B. Meteorological Conditions

Worst-case dispersion conditions can be associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), persistent wind direction, and relatively low mixing depths.[2] Under these conditions, increases in pollutant concentrations from both ground-level and elevated sources[3] are likely. These worst-case conditions differ at each site and are reflected in the predicted annual average pollutant levels between sites. Prolonged periods of air stagnation are uncommon in the Gillette area. However, meteorological conditions unfavorable for pollution dispersion occur approximately 30 percent of the time. Thus, plume impaction[4] and limited plume mixing due to temperature inversions at plume height can be expected with some regularity.[5]

The pollution dispersion potential for the Gillette area should vary considerably with the season and time of day. Pollution problems are most likely during fall and winter mornings when mixing depths and wind speeds are lowest. Dispersion potential is generally greatest during the spring.

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[1] These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are unknown, but high background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are assumed to be relatively low.

[2] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[3] Elevated sources are tall stacks that emit pollutants several hundred feet above ground. Ground-level sources include towns, strip mines, and tank farms that emit pollutants close to ground level.

[4] Plume impaction is the limited atmospheric mixing of stack plumes caused by elevated terrain (terrain as high as the plumes) and stable air conditions.

[5] See National Climatic Center. *Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities*. Asheville, N.C.: National Climatic Center, 1975.

9.2.2 Emission Sources

The primary emission sources in the Gillette scenario will be a power plant, three conversion facilities (Lurgi, Synthane, and Synthoil), supporting wells and surface mines, and those associated with population increases. The largest of these sources, the power plant, will have four 750-megawatt-electric boilers, each with its own stack.[1] The plant will be equipped with an electrostatic precipitator (ESP) which will remove 99 percent of particulates and a scrubber which will remove 80 percent of the SO_2 and 40 percent of the NO_x.[2] The plant's two 75,000-barrel storage tanks, with standard floating roof construction, will each emit up to 0.7 pound of HC per hour.

Most mine-related pollution will originate from diesel engine combustion products, primarily nitrogen oxides, HC, and particulates. Although water spray will be used to suppress dust, some additional particulates will occur from blasting, coal piles, and blowing dust.[3] Pollution from energy-related population increases will result largely from additional automobile traffic. Concentrations have been estimated from available data on average emissions per person in several western cities.

All the coal conversion facilities and the power plant will be cooled by wet forced-draft cooling towers. Each of the various cells in the cooling towers circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,200 pounds per year for each cell.[4]

Table 9-3 lists emissions of five criteria pollutants for all proposed facilities. The power plant is the greatest

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[1] Stacks are 500 feet high, have an exit diameter of 30.0 feet, mass flow rates of 2.56 x 10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

[2] These efficiencies were hypothesized as reasonable estimates of current industrial practices.

[3] The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency is investigating this question and will be used to inform further impact analyses.

[4] The power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

TABLE 9-3: EMISSIONS FROM FACILITIES
(pounds per hour)

Facilities	Particulates	SO_2	NO_x	HC	CO
3,000-MWe Power Plant					
Mine	12.6	8.3	113	69	13.1
Plant	1,196	6,440	15,812	440	1,464
Lurgi					
Mine	7	4.6	62	39	7.3
Plant	453	406	2,372	316	48
Synthane					
Mine	6	4	56	33	6.3
Plant	208	242	928	124	19
Synthoil					
Mine	10	6.8	92	56	11
Plant	316	946	4,616	1,330	181
25-MMtpy Export Coal Mine (rail)	13	8.3	113	69	13
25-MMtpy Coal Mine (slurry)	13	8.3	113	69	13
Natural Gas					
Gas Wells	0	0	0	1,000	0
Plant	0	433	0	0	0
Uranium					
Mine	0.1	0.1	0.5	0.3	0.1
Mill	0	0	7	0	0

CO = carbon monoxide
HC = hydrocarbons
MMtpy = million tons per year

MWe = megawatts-electric
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

contributor of pollutants in all cases except HC. Both the synthoil plant and the natural gas wells exceed the power plant in HC emissions.

9.2.3 Impacts

A. Impacts to 1980

1. Pollution from Facilities

The hypothetical strip mine for coal rail transport and natural gas wells will become operational in 1980. The greatest construction impact expected from these facilities will be periodic increases in particulate levels due to wind-blown dust. Since the highest particulate measurements do not exceed federal or state standards, blowing dust should not cause particulate problems as significant as those expected at Farmington or Kaiparowits (Chapters 6 and 7).

Tables 9-4 and 9-5 summarize the concentrations of four pollutants predicted to be produced by the strip mine and natural gas wells respectively. These pollutants (SO_2, particulates, NO_2, and HC) are regulated by federal and Wyoming state standards (also shown in the tables). Table 9-4 shows that the strip mine will not violate any federal or state ambient standards. Table 9-5 shows that, while typical concentrations from the natural gas wells do not violate ambient standards, peak concentrations may exceed both the federal and state HC standards by a factor of more than 6.

Tables 9-4 and 9-5 also list Non-Significant Deterioration (NSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] "Class I" is intended to designate the cleanest areas, such as national parks and forests.[2] Peak concentrations attributable to the strip mine for coal rail transport and from the natural gas wells do not exceed allowable Class II increments. However, both facilities do exceed Class I standards for 3-hour SO_2.

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[1] Non-Significant Deterioration standards apply only to particulates and sulfur dioxide.

[2] The Environmental Protection Agency initially designated all Non-Significant Deterioration areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class II. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

TABLE 9-4: POLLUTION CONCENTRATIONS FROM STRIP MINE FOR COAL RAIL TRANSPORT
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration^a				Standards^b				
	Background	Typical	Peak		Ambient			Non-Significant Deterioration	
			Plant	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates									
Annual	17		0.3	0	75	60	60	5	10
24-hour		6.0	12	0	260	150	150	10	30
SO_2									
Annual	10		0.2	0	80		60	2	15
24-hour		3.5	8	0	365		260	5	100
3-hour		10	40	0.1		1,300		25	700
NO_2^c									
Annual	6			0.2	100	100	100		
HC^d									
3-hour	Unknown	5.5		0.1	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical 25-million tons per year strip mine. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations near Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-5: POLLUTION CONCENTRATIONS FROM NATURAL GAS PRODUCTION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration^a				Standards^b				
			Peak		Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulate									
Annual	17		8	0	75	60	60	5	10
24-hour		8	8	2	260	150	150	10	30
SO_2									
Annual	28		2.6	2	80		60	2	15
24-hour		3.3	14.1	8	365		260	5	100
3-hour		14	55	0		1,300		25	700
NO_2^c									
Annual	4		3	0	100	100	100		
HC^d									
3-hour		55	1,087	0	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from natural gas production. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and [illegible] are attributable to the [illegible], with the exception of annual NO_2 levels. Concentrations over Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter [illegible].

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

Since Class I increments are violated by the facilities, they would have to be located a sufficient distance from such areas to allow dilution of emissions by atmospheric mixing to allowable concentrations prior to their reaching any Class I areas. The distance required for this dilution, which varies by facility type, size, emission controls, and meteorological conditions, in effect establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations would require a buffer zone of less than 5 miles between these facilities and a Class I area boundary.[1]

2. Pollution from the Town

The town of Gillette is expected to increase its population from 10,000 to 22,500 by 1980.[2] This increase will contribute to increases in pollution concentrations from urban sources. Table 9-6 shows predicted concentrations of five criteria pollutants measured at the center of the town and at a point 3 miles from the center of town.[3] When concentrations from urban sources are added to background levels, the HC levels will exceed ambient standards.[4]

B. Impacts to 1990

1. Pollution from Facilities

By 1990, the power plant, coal slurry pipeline, Lurgi gasification plant, uranium mill, and all associated mines will become operational. Typical and peak concentrations from the operation of these facilities are summarized in Tables 9-7 through 9-9. Air impacts from the strip mine supporting the coal slurry pipeline are not shown because they are expected to be similar to those produced by the strip mine for rail transport shown in Table 9-4. Impacts

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[1] Note that buffer zones around energy facilities will not be symmetrical. This lack of symmetry is clearly illustrated by area "wind roses" which show wind direction patterns and strengths for various areas and seasons. Hence, the direction of Non-Significant Deterioration areas from energy facilities will be critical to the size of the buffer zone required.

[2] Refer to Section 9.4.3.

[3] Pollution concentrations from population increases were computed under the assumption that urban emissions are directly proportional to population. Computational procedures are elaborated on in the Introduction to Part II.

[4] Hydrocarbon standards are violated regularly in most urban areas.

TABLE 9-6: POLLUTION CONCENTRATIONS AT GILLETTE
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]							Standards[b]		
	Background	Mid-Town Point			Rural Point					
		1980	1990	2000	1980	1990	2000	Primary	Secondary	Wyoming
Particulate										
Annual	17	22	27	31	5	7	27	75	60	60
24-hour		75	92	102	75	92	102	260	150	150
SO_2										
Annual	20	11	20	26	1	4	5	80		60
24-hour		41	48	56	41	48	56	365		260
3-hour		72	84	96	72	84	96		1,300	
NO_2[c]										
Annual	6	35	41	45	6	22	27	100	100	100
HC[d]										
3-hour	unknown	640	780	871	640	780	871	160	160	160
CO										
8-hour	unknown	2,200	2,550	2,970	2,200	2,550	2,970	10,000	10,000	10,000
1-hour		3,600	4,180	4,870	3,600	4,180	4,870	40,000	40,000	40,000

CO = carbon monoxide
HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and Secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 50 percent of nitrogen oxide from urban sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-7: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant, Averaging Time	Concentrations[a]					Standards[b]				
	Background	Typical	Peak			Ambient			Non-Significant Deterioration	
			Plant	Plant and Mine	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates										
Annual	37		0.6	0.4	0.2	75	60	60	5	10
24-hour		1.2	8.7	29	13	260	150	150	10	30
SO_2										
Annual	10		1.6	1.6	0.6	80		60	2	15
24-hour		3.9	47	51	40	365		260	5	100
3-hour		25	103	103	127		1,300		25	700
NO_2[c]										
Annual	6		4.6	4.6	2.5	100	100	100		
HC[d]										
3-hour		2.0	40	78	30	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations near Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 10.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-8: POLLUTION CONCENTRATIONS FROM STRIP MINE FOR COAL SLURRY LINE (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]				Standards[b]				
	Background	Typical	Peak		Ambient			Non-Significant Deterioration	
			Plant	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates									
Annual	17		0.3	0	75	60	60	5	10
24-hour		6.0	12	0	260	150	150	10	30
SO_2									
Annual	10		0.2	0	80		60	2	15
24-hour		3.5	8	0	365		260	5	100
3-hour		10	40	0.1		1,300		25	700
NO_2[c]									
Annual	6		2.9	0.1	100	100	100		
HC[d]									
3-hour		3.5	40	0.1	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical 25-million tons per year strip mine/coal slurry line. Annual average background levels are considered to be the best estimation of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Gillette are largely attributable to the plant.

[b] "Primary and secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-9: POLLUTION CONCENTRATIONS FROM LURGI GASIFICATION PLANT/MINE COMBINATION (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]					Standards[b]				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates										
Annual	17		0.3	1.3	0.1	75	60	60	5	-
24-hour		6.0	3.5	22	0.2	260	150	150	10	30
SO_2										
Annual	10		0.3	0.3	0.1	80		60	2	15
24-hour		1.	3.6	9.2	0.2	365		260	5	100
3-hour		1.7	18	26	0.6		1,300		25	700
NO_2[c]										
Annual	6		2.1	2.1	0.4	100	100	100		
HC[d]										
3-hour		0.3	3	30	0.2	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical Lurgi gasification plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations near Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 10.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

from uranium mining and milling are assumed slight and are therefore not shown. Peak concentrations from the new facilities and their mines are not expected to violate any federal or Wyoming ambient air standards.[1]

No Class II increments are violated by these facilities. However, several Class I increments are exceeded by both of the new plants and the strip mine. Peak concentrations from the strip mine, Lurgi gasification plant, and the power plant exceed all short-term (24-hour or less) Class I increments when combined with emissions from their associated mines. In addition, typical 3-hour SO_2 levels from the power plant equal the allowable Class I increment.

These PSD violations will require buffer zones for each plant. Current EPA regulations would require the largest buffer zone, 44 miles, for the power plant. The buffer zone for the Lurgi plant is 7.4 miles, and less than 5 miles for the strip mine. Currently there are no designated Class I areas within these buffer zones. Should the nearby Black Hills National Forest be redesignated Class I, however, the increments for Class I areas would be violated by the power plant.[2]

2. Pollution from the Town

Gillette's population increase to 19,950 by 1990 will cause urban pollutant concentrations to increase to the levels shown in Table 9-6. As in the 1980 case, the only federal or state ambient standard violated is that for HC.

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[1] Interactions of the pollutants from the plants are minimal due to the hypothetical distances between them. If the wind blows directly from one plant to another, plumes may interact. However, concentrations which result are less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentration). The predicted annual peak interaction increases are 0.4-0.5 micrograms per cubic meter (μg/m³) (particulates); 1.6-1.8 μg/m³ (sulfur dioxide), and 4.6-5.3 μg/m³ (nitrogen dioxide). The plants could have been sited such that short-term concentrations were highest for cases of plant interaction. Sensitivity analysis of this siting consideration will be done during the remainder of the study.

[2] The area is a "potential" Class I area because its current air quality makes it a prime candidate for redesignation and because recent congressional legislation, although not passed into law, has singled out national parks, forests, and recreational areas for mandatory Class I status.

C. Impacts to 2000

1. Pollution from Facilities

Two new facilities, a Synthane gasification plant and a Synthoil liquefaction plant, will become operational between 1990 and 2000. Tables 9-10 and 9-11 list typical concentrations from the plants, peak concentrations from the plants, and peak concentrations from the plant and mine combinations. These data show that the only violation will be the 3-hour peak HC concentrations emitted by the Synthoil plant, which will greatly exceed those allowed.[1]

Neither of the plants violates any Class II PSD increments, but both plant and mine combinations violate Class I increments for 24-hour and 3-hour SO_2. The Synthane plant also violates the Class I increment for 24-hour particulates when the pollutants from its associated mine are added under peak conditions. These pollutant concentrations would require buffer zones of 13 miles for the Synthoil plant and less than 5 miles for the Synthane plant.

2. Pollution from the Town

Gillette's population will increase to 65,100 by the year 2000, and increased pollution concentrations will be associated with this growth (Table 9-6). Still, only the HC ambient standard will be exceeded by this source; no other standard will even be closely approached.

9.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories of potential impacts are sulfates, oxidants,

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[1] Interactions between the Synthane and Synthoil plants will cause some increases in annual peak concentrations, but these concentrations are rather small (1.1 micrograms for sulfur dioxide, 5.5 for nitrogen dioxide, and 0.7 for particulates). These levels do not violate federal or Wyoming standards.

TABLE 9-10: POLLUTION CONCENTRATIONS FROM SYNTHANE GASIFICATION PLANT/MINE COMBINATION (micrograms per cubic meter)

Pollutant Averaging Time	Concentrations^a					Standards^b				
	Background	Typical	Peak			Ambient			Non-Significant Deterioration	
			Plant	Plant and Mine	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates										
Annual	17		0.1	0.2	0.1	75	60	60	5	10
24-hour		0.2	1.5	22	0.2	260	150	150	10	30
SO_2										
Annual	10		0.2	0.5	0.1	80		60	2	15
24-hour		1	5.2	0.4	0.3	365		260	5	100
3-hour		1.6	20	36	1.2		1,300		25	700
NO_2^c										
Annual	4		0.6	1.3	0.5	100	[illegible]	100		
HC^d										
3-hour		0.1	1.5	35	0.1	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical Synthane gas plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. [illegible] standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 2.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-11: POLLUTION CONCENTRATIONS FROM SYNTHOIL LIQUEFACTION PLANT/MINE COMBINATION (micrograms per cubic meter)

Pollutant Averaging Time	Concentration^a					Standards^b				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	[illegible]	Primary	Secondary	Wyoming	Class I	Class II
Particulates										
Annual	19		0.7	0.7	0.1	75	60	60	5	19
24-hour		1.3	6	6	0.3	260	150	150	10	37
SO_2										
Annual	27		3.6	3.6	2.4	80		60	2	20
24-hour		5.9	31	31	1.7	365		260	5	91
3-hour		23	109	109	5.9		1,300		25	512
NO_2^c										
Annual	4		4.4	6	2	100	100	100		
HC^d										
3-hour	unknown	300	25,100	25,100	5.5	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical Synthoil plant/mine combination. Annual average background levels are considered to be the best estimation of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over [illegible] are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 10.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

A. Sulfates

Very little is known about sulfate concentrations likely to result from western energy development. However, one study suggests that for oil shale retorting and coal gasification, peak conversion rates of SO_2 to sulfates in plumes are less than 1 percent.[2] Applying this ratio to plants in the Gillette scenario results in peak sulfate concentrations of less than 1 $\mu g/m^3$. This level is well below EPA's suggested danger point of 12 $\mu g/m^3$ for a 24-hour average.[3]

B. Oxidants

Oxidants (which include such compounds as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and brmine) can be emitted from specific sources or formed in the atmosphere. For example, oxidants can be formed when HC combines with NO_x. Too little is known about the actual conversion processes which form oxidants to be able to predict concentrations from power or liquefaction plants. However, the relatively low peak concentrations of HC from the power plant and its associated mine (78 $\mu g/m^3$) suggest that an oxidant problem is unlikely to result from these sources alone. An oxidant problem would more likely result from the combination of background HC and NO_2 emitted from the power plant plume. Since background HC levels are unknown, the extent of this problem has not been predicted.

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analysed during the remainder of the project. See: Hazardous Materials Advisory Committee, *Nitrogenous Compounds in the Environment*, U.S. Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

[2] Nordsieck, R., *et al*. *Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States*, Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975. This study assumed that sulfur dioxide (SO_2) in the plumes was converted to sulfate at the rate of 1 percent per hour independent of humidity, clouds, or photochemically related reaction intensity. Reported results indicate peak sulfate levels ranging from 0.1 to 1.6 percent of the corresponding peak SO_2 levels from oil shale retorting. Recent work in Scandinavia suggests that acid-forming sulfates arriving in Norway are complex ammonium sulfates formed by a catalytic and/or photochemical process which varies with the season.

[3] Ibid.

In only one of several cases investigated did oxidants formed from coal gasification plant emissions exceed federal standards.[1] (These cases are not comparable to the Lurgi and Synthane facilities hypothesized in this scenario; thus levels of oxidants formed from the combination of HC and NO_2 were not predicted.) Further, concentrations of HC in this scenario are much smaller than those found in the one case in which standards were violated. Although the NO_2 levels in that case are about equal to those expected from the gasification facilities in this scenario, violations of oxidant concentrations are not expected. However, this is not the case for the Synthoil plant, which produces peak HC concentrations more than 150 times greater than the federal and state standards. Since NO_2 is emitted in the plume, violations of oxidant standards may result.

HC concentrations over Gillette, which will reach a level five times the standard by the year 2000, are also likely to create oxidant problems. Since oxidant formation may occur relatively slowly (i.e. one or more hours) this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Fine Particulates

Fine particulates (less than 3 microns in diameter) are primarily ash and coal particles emitted by the plants.[2] Current information suggests that particulate emissions controlled by ESP have a mean diameter of less than 5 microns, and uncontrolled particulates have a mean diameter of about 10 microns.[3] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles emitted by the plant. The high-efficiency ESP's (99-percent removal) in this scenario are estimated to remove enough course particulates that fine particulates account for about 50 percent of the total particulate concentrations. This percentage applies to the power plant and Lurgi and Synthane gasification processes. However, since only half of the particulate emissions from the Synthoil plant are controlled, about 25 percent of its emissions will be fine particulates. Health effects from fine particulates are discussed in Section 12.6.

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[1] Nordsieck, R., *et al.* *Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States*. Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975.

[2] Fine particulates produced by atmospheric chemical reactions take long enough to form so they occur long distances from the plants.

[3] Fifty percent of the mass is contained in particles this diameter. Eppright, B.R., *et. al.* *A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station*. Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

D. Long-Range Visibility

One impact of very fine particulates (0.1-0.1 microns in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light, which ultimately reduces the contrast between an object and its background below the level required by the human eye to distinguish the object from the background. Estimates of visual ranges for this scenario are based on empirical relationships between visual distance and fine particulate concentrations.[1]

Visibility in the region of this scenario generally averages about 70 miles. The greatest reduction in average visibility, due to an increase in suspended particulates, will occur when looking south-southeast roughly on a line from the Lurgi to the Synthoil plant. As the facilities in this scenario become operational, average visibility will decrease to 67 miles by the year 2000. Air stagnation episodes will cause substantially greater reductions.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although ESP will remove enough particulates for the power plant to meet emission standards, stack plumes would probably exceed the 20-percent opacity standard.[1] Thus, plumes will be visible at the stack exit and for some distance downwind. Although no opacity standards exist for gasification or liquefaction plants, the Lurgi, Synthane, and Synthoil plants all have more than one stack which would produce plumes with greater than 20-percent opacity.

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[1] Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." Atmospheric Environment, Vol. 2 (September 1968), pp. 455-64. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

F. Cooling Tower Salt Deposition

Estimated salt deposition rates from cooling tower drift for the four facilities in this scenario are shown in Table 9-12. These rates are relatively low and decrease rapidly beyond 1.3 miles. Some interaction of salt deposition from the various plants will occur. For example, the area midway between the power plant and the Synthane plant will receive an average of about 3.7 pounds per acre per year. The effect of salt on a specific area depends on soil conditions, rainfall, and existing vegetation.

TABLE 9-12: SALT DEPOSITION RATES

Plant	Averaging Salt Deposition Rate (pounds per acre per year)		
	0-1.3 miles[a]	1.3-10.0 miles[a]	10.0-33.1 miles[a]
Lurgi gasification	12	0.7	0.03
Power plant	70	3.4	0.2
Synthane gasification	6.6	0.3	0.02
Synthoil liquefaction	17	0.8	0.05

[a] Diameter of circles bounding the area subject to the salt deposition rate.

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[1] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal units heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require removal of 99.9 percent of all plume particulates, which would increase electrostatic precipitator costs.

G. Cooling Tower Fogging and Icing

Fogging potential in the Gillette area is generally low. Relative humidities of 100 percent occur less than twice per year, and humidities between 95 and 99 percent occur less than four times per year. In addition, heavy fog (visibility reductions to .25 mile or less) occurs on the average only about 8 days annually. Hence, cooling towers should produce only slight increases in fogs. However, the Gillette area has approximately 100 days of subfreezing temperatures each year, and thus cooling tower drift may add significantly to icing problems in the immediate plant vicinities when conditions are right. This could cause hazardous driving conditions on nearby Interstate 90 and U.S. Highway 14.

H. Trace Element Emissions

Trace element emissions from the Gillette facilities depend on coal composition and the concentration of elements in ash, liquid wastes, and stack plumes. Although some portion of all trace elements in Gillette coal (shown in Table 9-13) are expected to enter the atmosphere, the exact percentage cannot be predicted. Some trace element emissions can be predicted for power plants, but information is not available for determining concentrations from liquefaction or gasification facilities.

Compared with the lignites of the Northern Great Plains region, Gillette coal contains low amounts of arsenic, mercury, and uranium but two to three times more lead and zinc. Compared with Southwestern coal, Gillette coal contains nearly twice the concentrations of arsenic and lead.

9.2.5 Summary of Air Impacts

A. Air Quality

Of the new facilities projected in the Gillette scenario, only the Synthoil liquefaction plant and the natural gas wells violate federal or Wyoming ambient standards. However, the 3-hour HC standard is greatly exceeded, with levels from the Synthoil plant exceeding the standard by a factor of more than 150.

Each of the facilities will violate several PSD Class I increments. Peak concentrations from the Synthoil plant will exceed Class I increments for 24-hour particulates and all three SO_2 increments. Peak concentrations from the coal rail transport and the coal slurry line strip mines, as well as those from the gasification plants, will violate Class I increments for 24-hour particulates, 24-hour SO_2, and 3-hour SO_2. The power plant and natural gas well peak concentrations will violate 24-hour and 3-hour SO_2 increments. Because of these violations, the power

TABLE 9-13: SELECTED TRACE ELEMENT COMPOSITION OF GILLETTE

Element	Range of Composition[a] (parts per million)			To Conversion Facilities[b] (pounds per day)
	Low	Average	High	
Arsenic	1	1.850	4	418
Beryllium	0.15	0.240	0.70	56
Cadmium	0.10	0.130	0.20	30
Copper	3.30	13.600	51	3,163
Fluorine	30	56.250	200	13,000
Mercury	0.06	0.109	0.28	25.3
Lithium	0.50	4.440	49	1,032
Lead	1.50	6.550	40	1,523
Antimone (Sb)	0.10	0.260	0.70	59.3
Selenium	0.30	0.950	2.20	221
Thorium	1.50	2.380	7.70	552
Uranium	0.20	0.920	3.20	212
Zinc	2.10	7.150	25	1,662

[a] Based on data from Wyodak-Anderson coal bed of the Belle Ayr (Amax) mine and the Wyodak mine at Gillette. Ranges and averages based on 20 samples.

[b] Obtained by multiplying the average concentration by the total quantity mined for conversion facilities: 116,300 tons per day (232,600,000 pounds per day).

plant will require a buffer zone of 44 miles, the Synthoil plant will need a 13-mile buffer zone, and the Lurgi plant will need a 7.4-mile buffer zone. The Synthane plant, strip mines, and natural gas wells will require buffer zones of under 5 miles.

Population increases in Gillette will add to existing pollution problems. Current violations of HC standards will continue to increase through the year 2000, but no other violations of ambient standards due to urban sources are expected in Gillette.

Several other categories of air impacts have received only preliminary attention. Our information to date suggests that oxidant and fine particulate problems are likely to emerge, largely owing to emissions from the Synthoil plant. Plumes from the stacks at all the plants will be visible and, in some cases, may exceed the 20-percent opacity standard. Mercury and beryllium emissions from the power plant will also exceed the existing standards for some industrial plants, although no standards currently exist for coal-fired power plants. Long-range visibility will be reduced from the current average of 70 miles to about 67 miles some time after the year 2000.

B. Alternative Emission Controls

Pollution concentrations from the power plant will vary if emission control systems with other efficiencies are used.[1] For example, Table 9-14 gives the SO_2, particulate, and NO_x concentrations which would result if the plant used only enough control to meet most New Source Performance Standards; that is, if the plant removed 97.5 percent of the particulates and none of the SO_2, rather than the 99-percent and 80-percent removals hypothesized in this scenario. These data show that resulting concentrations would violate only the federal standards for 3-hour SO_2.

TABLE 9-14: CONCENTRATIONS FROM MINIMAL EMISSION CONTROLS[a]

Pollutant Averaging Time	Concentration	Federal[b] Standard	Wyoming Standard
SO_2			
Annual	8	80	60
24-hour	235	365	260
3-hour	1,615	(1,300)	
Particulate			
Annual	1	75	60
24-hour	22	260	150
NO_x			
Annual	8	100	100

NO_x = nitrogen oxides SO_2 = sulfur dioxide

[a] These are maximum concentrations which assume 97.5 percent particulate removal and no SO_2 removal, which would meet New Source Performance Standards.

[b] Primary standards protect public health and secondary standards protect public welfare. Secondary standards are in parenthesis.

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[1] New Source Performance Standards do not exist for gasification and liquefaction plants. The Lurgi, Synthane, and Synthoil plants meet all Class II increments in this scenario.

TABLE 9-15: REQUIRED EMISSION REMOVAL FOR MEETING CLASS II INCREMENTS

Pollutant Averaging Time	Emission Removal (%)
SO_2	
Annual	0
24-hour	58
3-hour	57
Particulates	
Annual	75
24-hour	96.6

SO_2 = sulfur dioxide

Other alternatives are for the plants to increase the efficiency of emission controls or to reduce total plant capacity to meet all NSD Class II increments. Since all plants in the Gillette scenario meet allowable Class II increments with the hypothesized controls, no reduction in capacity or improvement in control efficiency is required (Table 9-15).

C. Data Availability

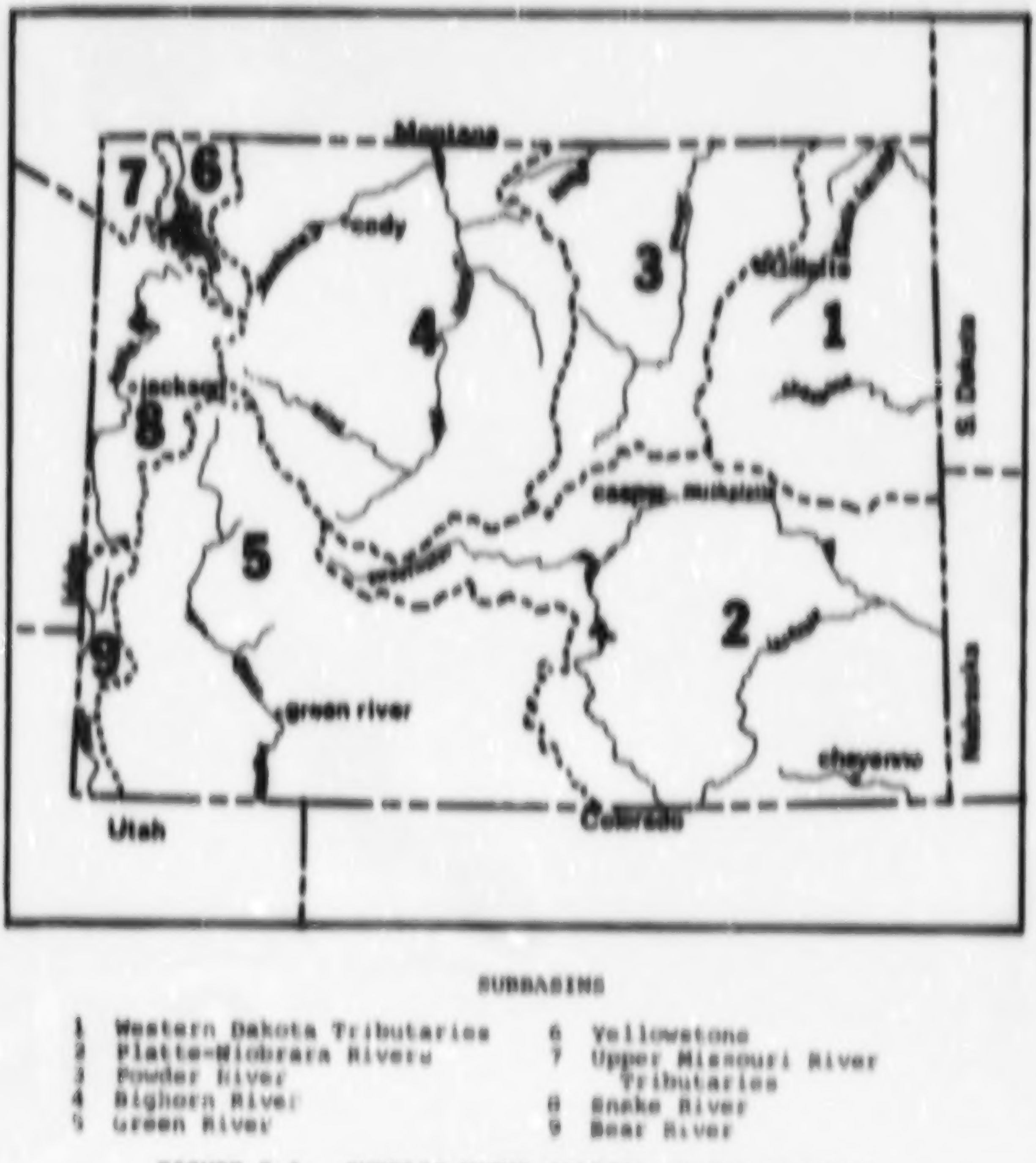
Availability and quality of data have limited the impact analyses reported in this chapter. These factors have primarily affected estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials. Expected improvements in data and analysis capacities include:

1. Improved understanding of pollutant emissions from electrical generation. This includes the effect of pollutants on visibility.
2. More information on the amounts and reactivity of trace elements from coals. This would improve estimates of fallout and rainout from plumes.

9.3 WATER IMPACTS

9.3.1 Introduction

As shown in Figure 9-3, the Gillette, Wyoming scenario is located in a water-poor area of the relatively water-rich Upper Missouri River Basin. Surface water sources that could supply the needs of energy development at Gillette are all a considerable distance away; these include the Yellowstone River, its tributaries,



SUBBASINS

1 Western Dakota Tributaries
2 Platte-Niobrara Rivers
3 Powder River
4 Bighorn River
5 Green River
6 Yellowstone
7 Upper Missouri River Tributaries
8 Snake River
9 Bear River

FIGURE 9-3: SURFACE WATER SOURCES IN THE VICINITY OF GILLETTE

and the Belle Fourche, Green, and North Platte Rivers. In this area, annual rainfall is about 14 inches, and annual snowfall is about 48 inches.

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

9.3.2 Existing Conditions

A. Groundwater

The most productive aquifer systems in the Gillette area are the deeply buried Madison Limestone aquifer (mostly over 5,000 feet deep), shallow aquifer systems in the Fort Union and Wasatch Formations (mostly less than 300 feet deep), and alluvial aquifer systems associated with the surface drainage. Although no estimate is available on the quantity of water stored in these aquifers (information is especially inadequate for the Madison), the total volume of groundwater available in the northeast Wyoming region without exceeding recharge rates is estimated at 150,000 acre-feet per year (acre-ft/yr).[1]

The quality of water in the Madison aquifer, as measured by total dissolved solids (TDS) concentrations, ranges from less than 500 milligrams per liter (mg/l) near recharge areas in the Powder River Basin to more than 4,000 mg/l near the Montana-North Dakota line.[2]

Water from the Madison has municipal, industrial, domestic, and livestock uses in the Wyoming region. Because the Madison is a limestone aquifer with irregular caverns storing the water, the productivity of a particular well depends on the number or size of caverns encountered by the well borehole. Wells producing several hundred gallons per minute (gpm) are common.

Several alluvial aquifers are present along the streams in the scenario area. The aquifer along Donkey Creek, about 5 miles east of Gillette, is the most productive, having wells that yield from only a few to as much as several hundred gpm[1] at a depth of from 3 to 20 feet.[2] Water quality of these alluvial aquifers is generally only fair,[3] and the water is presently used only for livestock and domestic purposes.

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[1] U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

[2] Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 3.

The most important aquifers in the Gillette area are in the shallow bedrock Fort Union and Wasatch Formations. These aquifers are in coal beds and lens-like sandstone bodies interbedded with shales. Wells yield up to 100 gpm in the Fort Union Formation and up to 500 gpm in the Wasatch Formation.[4] Water taken from these formations is used for livestock and domestic purposes as well as more than 95 percent of Gillette's municipal water supply.[5] Water quality is variable, with a generally lower concentration of TDS than the alluvial aquifers.[6]

B. Surface Water

As shown in Figure 9-3, Gillette, Wyoming is located approximately on the divides of several major watersheds: the Belle

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[1] Wyoming, State Engineer's Office. *A Report from the Wyoming Water Planning Program*. Cheyenne, Wyo.: Wyoming, State Engineer's Office, 1972, p.61.

[2] U.S., Department of the Interior, Bureau of Land Management, et al. *Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming*, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974, p. I-95.

[3] Total dissolved solids range from about 500 to more than 2,000 milligrams per liter (mg/ℓ), but most water ranges from 1,000 to 1,500 mg/ℓ. See BLM. *FEIS: Eastern Powder River Coal Basin*, p. I-199.

[4] Wyoming, State Engineer's Office. *Wyoming Water Planning Program*, pp. 67, 70.

[5] Northern Great Plains Resources Program, Water Work Group, Ground Water Subgroup. *Shallow Ground Water in Selected Areas in the Fort Union Coal Region*. Open File Report 74-48. Helena, Mont.: U.S., Department of the Interior, Geological Survey, 1974, p. 35.

[6] The total dissolved solids content ranges from 300 to more than 2,000 milligrams per liter, but the range of most bedrock aquifer water in the Powder River Basin is limited to 500-1,500 dissolved solids. BLM. *FEIS: Eastern Powder River Coal Basin*, p. I-130.

Fourche, Little Powder, Cheyenne, and Powder River Basins. Therefore, as energy development takes place around Gillette, the water needs could be met from several of these sources.

The water supply situation is complicated by the Yellowstone Compact[1] and the Belle Fourche Compact.[2] The Yellowstone Compact was negotiated between Wyoming, Montana, and North Dakota to control water allocations in the Yellowstone River Basin. The compact recognizes all water rights existing in the basin as of January 1, 1950 and provides for the division of all remaining (unallocated) flow. Flow in the tributaries to the Yellowstone is divided as shown in Table 9-16.

However, an important provision within the compact states that no water will be diverted out of the basin without the consent of the signatory status. As Gillette is outside the Yellowstone Basin, this provision will directly affect the availability of water to energy development.

Water appropriations in the Belle Fourche River are governed by a compact between Wyoming and South Dakota. This compact states that all waters unappropriated as of February 1944 are allocated 10 percent to Wyoming and 90 percent to South Dakota. There are several intermittent streams in the scenario area. Although there are no data on these streams, it is doubtful that they have enough flow to supply water for energy development. Gillette is located on Donkey Creek, an ephemeral tributary of the Belle Fourche River, but the drainage area of the creek above Gillette is only 0.38 square mile.

TABLE 9-16: LEGAL DIVISION OF FLOW, YELLOWSTONE RIVER TRIBUTARIES

Tributary	Wyoming	Montana
Clarks Fork	60%	40%
Bighorn	80%	20%
Tongue	40%	60%
Powder	42%	58%

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[1] Yellowstone River Compact of 1950, 65 Stat. 663 (1951).

[2] Belle Fourche River Compact of 1943, 58 Stat. 94 (1944).

The availability of water to meet energy development demands is shown on Table 9-17. Surface water would be available from several distant sources, including the Yellowstone River and its tributaries, Belle Fourche River, Cheyenne River, Little Missouri River, Green River, North Platte River, and Lake Oahe on the Upper Missouri in South Dakota. This is discussed further in the next section.

9.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements for energy facilities hypothesized for the Gillette scenario are shown in Table 9-18. Two sets of data are presented. The Energy Resource Development System data are based on secondary sources, including impact statements, Federal Power Commission docket filings, and recently published data accumulations,[1] and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water use requirements and take into account the moisture content of the coal being used and local meteorological data.[2]

Figure 9-4 shows the water consumed for different purposes by the hypothesized energy facilities. As indicated, more water is used for cooling than for processing and solids disposal combined. Solids disposal consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

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[1] The Energy Resource Development System, which is forthcoming as a separate publication, is based on data drawn from: University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975. Radian Corporation. A Western Regional Energy Development Study. Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

[2] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 9-17: WATER USE AND AVAILABILITY FOR TRANSPORT FOR ENERGY DEVELOPMENT AT GILLETTE[a]

(in acre-feet per year)

		Estimated Depletions of Stream Flow						
Stream	Flow Leaving Northeastern Wyoming	Irrigation	Municipal Domestic & Stock	Industrial	Reservoir Evaporation	Total	Water Yield from Northeastern Wyoming	Wyoming's[b] Legal Share
Tongue River	302,700	77,100	2,400	1,300	3,100	83,600	386,300	96,000
Powder River	322,600	66,100	2,100	700	27,600	96,500	419,100	112,000
Little Missouri River	11,400	1,810	100	—	3,120	4,000	15,400	—
Belle Fourche River	76,400	1,540	1,000	1,300	16,400	21,100	96,700	7,000
Cheyenne River	64,800	4,500	400	1,700	16,100	20,965	85,700	15,000[c]
Bighorn River								1,000,000
Total	797,900	151,000	6,200	4,400	62,700	225,300	1,022,200	1,178,000

[a] U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming. 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

[b] Wyoming, State Engineer's Office, Water Planning Program. The Wyoming Framework Water Plan. Cheyenne, Wyo.: Wyoming State Engineer's Office, 1973.

[c] No legal restriction.

TABLE 9-18: WATER REQUIREMENTS FOR ENERGY DEVELOPMENT

Use	Size	Requirement[a] Acre-ft/yr	
		ERDS[b]	WPA[c]
Power Generation	3,000 MWe	42,000	36,330
Gasification (Lurgi)	250 MMscfd	7,460	6,420
Coal Slurry	25 MMtpy	18,390	18,490
Gasification (Synthane)	250 MMscfd	10,100	8,380
Liquefaction (Synthoil)	100,000 bbl/day	19,400	9,780
Gas Wells	250 MMscfd	3,800	
Uranium Production	1,100 mtpd of ore	1,350	

bbl/day = barrels per day
MMscfd = million standard cubic feet per day
MMtpy = million tons per year
mtpd = metric tons per day
MWe = megawatt(s)-electric

[a] Requirements are based on an assumed load factor of 100-percent. Although not realistic for sustained operation, this load factor will generate the maximum water demand for these facilities.

[b] Chapter 3 of White, Irvin L. *et al*. *Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c] From Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The load factors assumed in the report are different for different technologies. Data were changed to correspond to 100-percent load factor in this table.

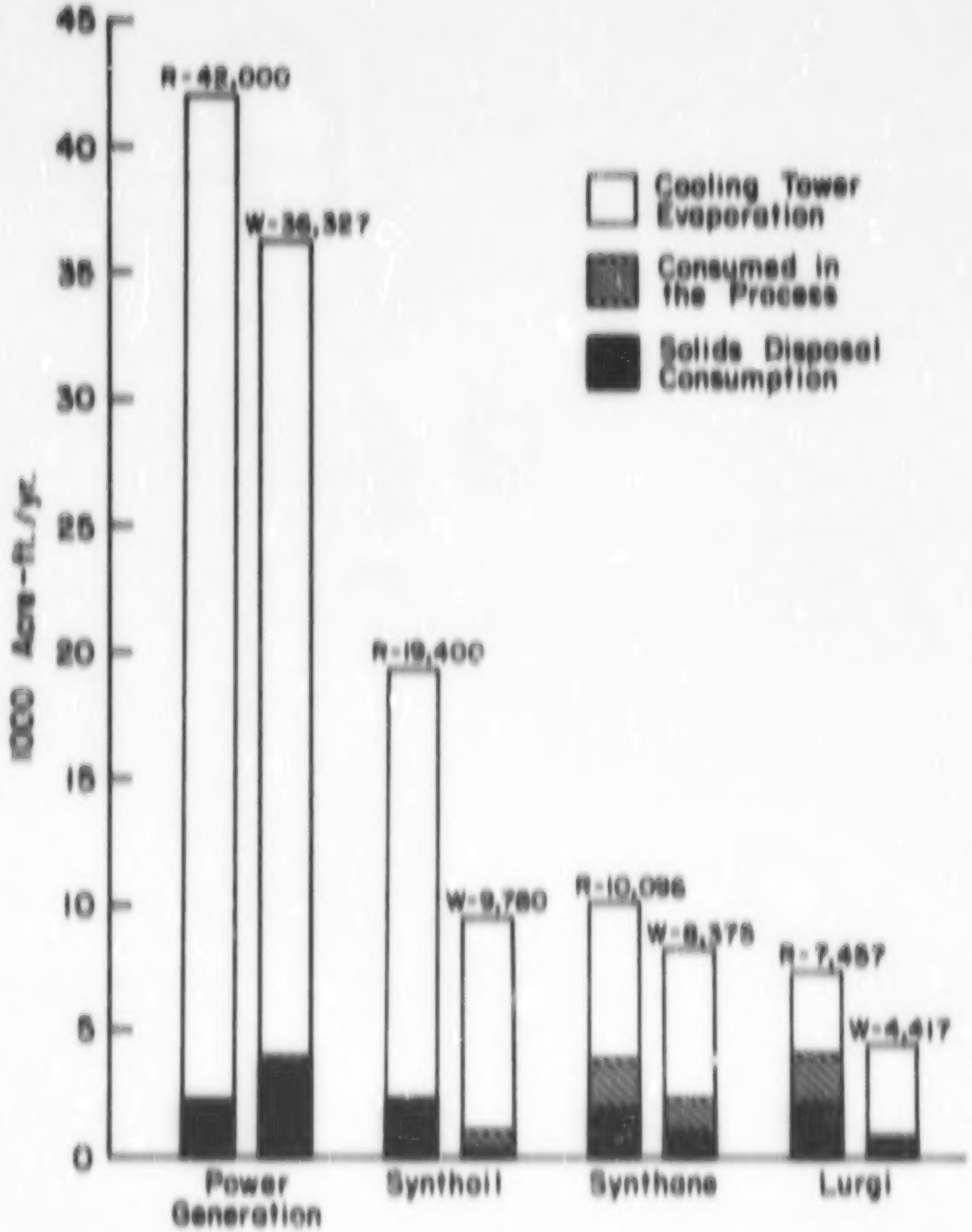

FIGURE 9-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE GILLETTE SCENARIO

TABLE 9-19: WATER REQUIREMENTS FOR RECLAMATION[a]

Mine	Acres Disturbed/Year	Maximum Acres Under Irrigation	Water Requirements (Acre-ft/yr)
Power Plant	110	550	415
Lurgi	85	425	320
Synthane	85	425	415
Synthoil	110	550	415
Rail Transport	220	1,110	825
Slurry Pipeline	220	1,110	825
Total	830	4,150	3,215

[a] Based on an irrigation rate of 9 inches per year for 5 years, which is the difference between water demand of native grasses and average precipitation. See U.S., Department of the Interior, Bureau of Land Management, Resource and Reclamation Evaluation: Otter Creek Study Site, EMRIA Report No. 1. Billings, Mont.: Bureau of Land Management, 1975.

In addition to the energy facility water requirements, the associated mines that provide feedstock coal will also require water. If reclamation of surface-mined lands includes irrigation, most of the water requirements for mining will be for reclamation (see Table 9-19).

Assuming the legal restraints of the various compacts mentioned earlier can be favorably resolved, several pipeline or aqueduct schemes for supplying Gillette with water have been evaluated by industry and government agencies. Figure 9-5 shows some of these schemes. Table 9-20 presents representative flow data at possible diversion points from these rivers and some water quality parameters of interest.

The cost of transporting water to the energy development will depend on several factors, including the route selected and the volume of flow. Cost figures for some of these diversions are shown on Table 9-21.

The cost required to bring large quantities of water into Gillette may be such that only a federal organization, such as the Bureau of Reclamation, would be able to finance the construction. However, a consortium of private companies might fund a water system for all the developments and thus be able to take

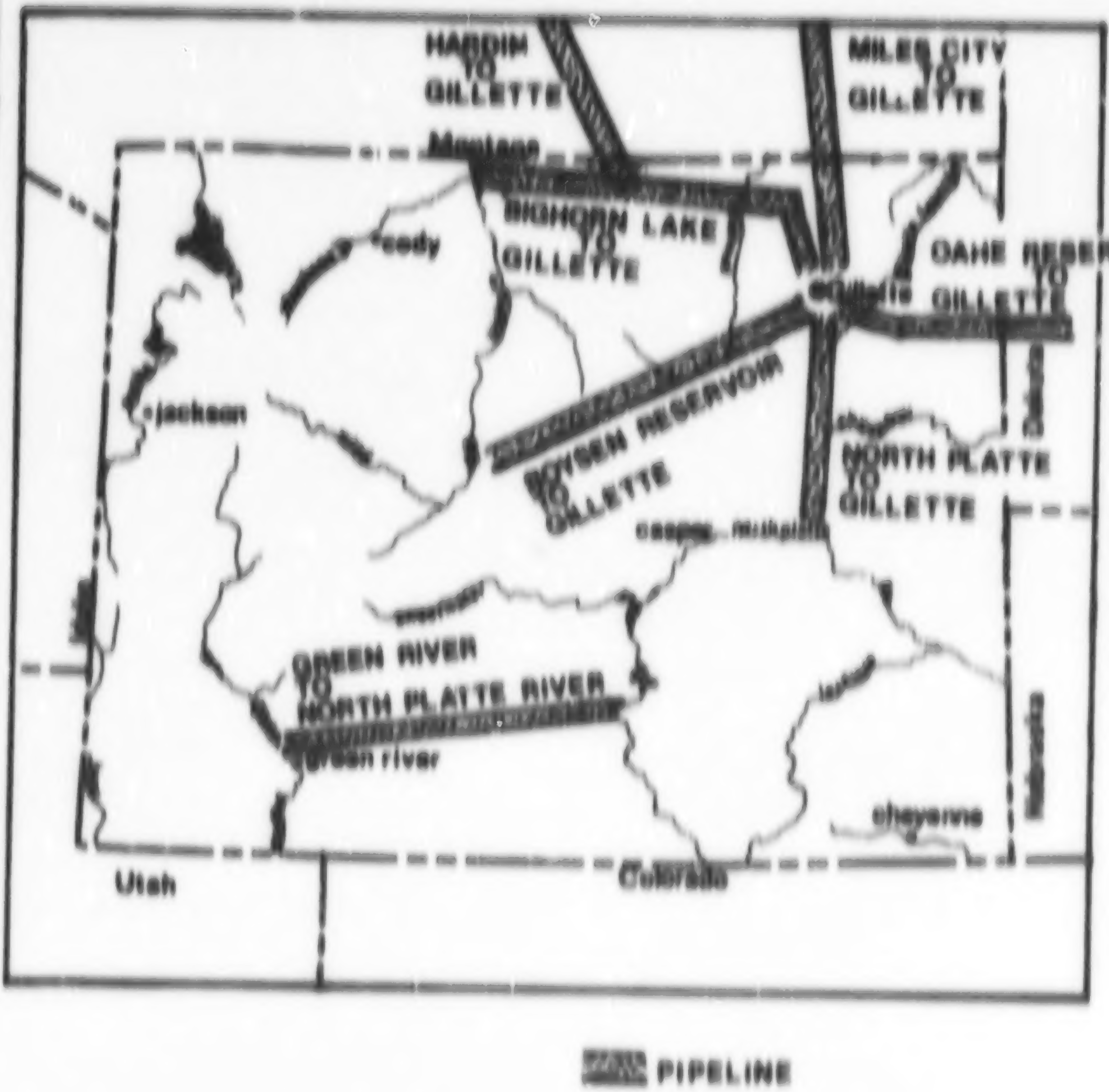

FIGURE 9-5: ALTERNATE WATER SUPPLY ROUTES FOR GILLETTE DEVELOPMENT

TABLE 9-20: STORAGE, FLOW, AND QUALITY DATA FOR POSSIBLE WATER DIVERSION POINTS TO SUPPLY DEVELOPMENT AT GILLETTE

River	Location	Drainage Area (Sq. Mi.)	Minimum Flow (cfs)	Maximum Flow (cfs)	Average Flow (acre-ft/yr)
Green River	Green River, WY	≈ 9,700^a	170	26,500	1,349,000
North Platte	Near Glenrock, WY	12,300^a	176	18,000	
Bighorn	Hardin, MT	1,101	0.2	4,520	205,970
Yellowstone	Miles City, MT	10,400	996	96,300	8,266,520
Nowood	Tensleep, WY	803	0.7	3,330	76,800
Reservoir	**River Basin**	**Inactive and Dead Storage (acre-feet)**	**Active Storage (acre-feet)**	**Flood Storage (acre-feet)**	**Total Storage (acre-feet)**
Boysen	Bighorn	252,100	548,900	151,400	952,400
Bighorn	Bighorn	552,300	613,700	259,000	1,375,000
River	**Location**	**D.O.**	**TDS**	**pH**	**Total Hardness**
Green River	Green River, WY	7.5-12	261-762^b	7.4-8.7^c	160-260^c
North Platte	Near Glenrock, WY		181-1,002^b		
Bighorn	Hardin, MT		170-1,360	7.5-8.3	300-540
Yellowstone	Miles City, MT		150-626	6.9-8.5	46-206
Nowood	Tensleep, WY		517-885^c	8.0-8.3	280-405^c

≈ = approximate
cfs = cubic feet per second
D.O. = dissolved oxygen
pH = acidity
Sq. Mi. = square miles
TDS = total dissolved solids

[a] Contributing at diversion point.

[b] Calculated from specific conductance.

[c] 1973-1974.

TABLE 9-21: ALTERNATIVE WATER SUPPLY COSTS FOR GILLETTE[a]

Service Area	Water Sources	Diversion Point	Cost Per Acre-Foot (Dollars)
Gillette, Wyoming vicinity and south	Bighorn River	Bighorn Lake	270
	Bighorn River	Hardin, Montana	250
	Yellowstone River	Miles City, Montana	220
	Missouri River	Oahe Reservoir, South Dakota	294
	Green River	Rock Springs, Wyoming	235

Source: Gibbs, Phil Q. "Availability of Water for Coal Conversion," Preprint No. 2561. Paper presented at the American Society of Civil Engineers National Convention, Denver, Colorado, November 1975.

[a] Assumptions - 8% interest
8 mills/kilowatt hour for pumping
40 year repayment of capital costs
flow 300,000-600,000 acre-feet per year

advantage of economies of scale. In effect, this could mean that the timing of facility completions and subsequent start-ups would be at more defined intervals. Several facilities might come on-line at the same time to match the completion of an increment of the water supply system. Although the costs shown in Table 9-21 are for a 300,000-600,000 acre-ft/yr delivery rate, this volume may not be provided in one step. Alternatively, individual industries may provide their own water supply systems. The cost of individual systems would be higher but might still be within the economic limits of project feasibility.

In the immediate vicinity of Gillette, the Madison aquifer is too deep (10,000-14,000 feet)[1] for economical use, but about 50 miles to the east the aquifer is only about 1,500 feet from the surface and thus could be economically tapped and pumped by pipeline to the scenario area. Such a system could be used to supply some of the water needs for energy development.

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[1] Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974.

The water supply system postulated for this scenario assumes that, rather than a single water-supply pipeline, the industries will use major surface and groundwater sources, and water will be pumped to the industrial site. The Lurgi and Synthane gasification plants and the power plant will draw water from the Yellowstone River at Miles City. The Synthoil liquefaction plant and coal slurry facility will take water from the North Platte River near Douglas. Water for the rail transport facility will be taken from local, shallow aquifers in the Fort Union Formation. This water will be obtained from mine dewatering operations. Water for the uranium mill and the gas liquefaction plant will be withdrawn from the Madison limestone aquifer in the vicinity of Sundance.

B. Municipal Supply

Most of the municipal water supply will probably be taken from groundwater supplies. Although the water supply for Gillette is presently derived from a local well field, water probably will be pumped in the future from the Madison aquifer in the vicinity of Sundance. Additional water for Casper will be obtained by increased development of existing sources. Requirements for increased population growth are shown in Table 9-22.

TABLE 9-22: WATER REQUIREMENTS FOR INCREASED POPULATION GROWTH[a]
(acre-ft/yr)

Year	Rural[b] Campbell County	Gillette[c]	Casper[d]	Total
1980	30	2,690	470	3,190
1990	70	5,1[illegible]	1,410	6,590
2000	110	8,450	2,000	10,560

[a] Above 1975 level.

[b] Based on 80 gallons per capita per day.

[c] Based on 240 gallons per capita per day.

[d] Based on 200 gallons per capita per day. U.S., Department of the Interior, Geological Survey, Estimated Use of Water in the United States in 1970, Circular 676. Washington, D.C.: Government Printing Office, 1972.

9.3.4 Water Effluents

A. Energy Facilities

The quantities and types of waste streams from the energy facilities hypothesized for the Gillette scenario are shown in Table 9-23. The largest quantity of effluents are from flue gas desulfurization and ash disposal. The ash content of Gillette coal is 8 percent and is disposed of as fly ash or bottom ash, depending on the conversion process. The quantity of flue gas desulfurization effluent depends on the sulfur content of the coal (0.6 percent by weight on a dry basis) and the scrubber efficiency (80-percent removal assumed). Other residual quantities are insignificant.

All discharge streams from the facilities will be funneled into clay-lined, on-site evaporative holding ponds. There are no intentional releases to surface or groundwater systems. Runoff prevention systems will be installed in all areas that have a pollutant potential. Runoff will be directed to either a holding pond or a water treatment facility.

The uranium mine will have both gaseous and particulate emissions of radioactive materials, but the concentrations at the plant boundaries will not be significant. Runoff from the mine area will be controlled to restrict the flow of radioactive solids. After settling, mine water will have about the same quality as local springs.[1] Typical mine water qualities are shown in Table 9-24.

The uranium milling plant will also have liquid wastes. Sanitary sewage will be treated and the effluent will be used as process water; sludges will be placed in a landfill. Tailings from the uranium mill will be ponded as a slurry in a manner similar to that described above for the other facilities.

B. Municipalities

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drainfields), and the urban population will require waste treatment facilities. The current status of wastewater treatment facilities in the municipalities most affected by energy development activities is

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[1] U.S., Atomic Energy Commission, Directorate of Licensing, Fuels and Materials. Environmental Survey of the Uranium Fuel Cycle. WASH-1248. Washington, D.C.: Atomic Energy Commission, 1972.

TABLE 9-23: EFFLUENTS FROM TECHNOLOGIES USED BY CLUSTER[a]

		Power Generation			Lurgi			Synthane			Synthoil		
Process	Stream Content[b]	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (gpm)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (gpm)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (gpm)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (gpm)
Cooling-Towers Sludge	O	—	—	—	111	23	26	127	23	26	40	13	6
Boiler Demineralizer Waste	O	3.3	1.1	0.1	29	26	2	26	22	2	9	6	0.7
Treatment Waste	O	—	—	—	22	11	1.8	31	26	2.6	17	9	1.6
Treatment Waste	I	280	100	29	25	6	1.5	27	23	2	71	26	4.3
Flue Gas Desulfurization		1,961	784	295	181	72	20	180	76	27	—	—	—
Bottom Ash Disposal	I	665	480	23	1,490	1,137	62	360	281	20	3,609	2,776	120
Fly Ash Disposal	I	2,336	1,861	77	251	176	7	1,487	1,127	47	—	—	—
Total		5,250.3	3,226.1	555.1	2,089	1,555	286.1	2,243	1,580	251.6	3,756	2,830	134.6

gpm = gallons per minute
tpd = tons per day

[a] From Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S. Environmental Protection Agency, forthcoming. Figures were adjusted to correspond to a load factor of 100 percent. See Appendix B.

[b] S=soluble inorganic
I=insoluble inorganic
O=insoluble organic

TABLE 9-24: URANIUM MINE WATER COMPOSITION[a,b]

UNDERGROUND MINES				
Applicant	Cotter Corp.	Union Carbide	Union Carbide	Union Carbide
Mine Designation	Schwartz-walder	[illegible]	Martha Bell	Burro
Mine Location	Golden, Colorado	Uravan, Colorado	Uravan, Colorado	Slick Rock, Colorado
Flow rate, thousands gpd	[illegible]	[illegible]	[illegible]	[illegible]
pH	[illegible]	[illegible]	[illegible]	[illegible]
Alkalinity (as $CaCO_3$)	[illegible]	[illegible]	[illegible]	[illegible]
BOD, 5-day	[illegible]	[illegible]	[illegible]	[illegible]
COD	[illegible]	[illegible]	[illegible]	[illegible]
Total Solids	[illegible]	[illegible]	[illegible]	[illegible]
TDS	[illegible]	[illegible]	[illegible]	[illegible]
Total Suspended Solids	[illegible]	[illegible]	[illegible]	[illegible]
Total Volatile Solids	[illegible]	[illegible]	[illegible]	[illegible]
Ammonia (as N)	[illegible]	[illegible]	[illegible]	[illegible]
Kjeldahl Nitrogen	[illegible]	[illegible]	[illegible]	[illegible]
Nitrate (as N)	[illegible]	[illegible]	[illegible]	[illegible]
Phosphorus Total as P	[illegible]	[illegible]	[illegible]	[illegible]
Alpha-Total[c]	[illegible]			
Beta Total[c]	[illegible]			
Gamma Total[c]	[illegible]			

OPEN PIT MINES			
Applicant	Kerr-McGee	Getty Oil	Utah Intl.
Mine Designation	---	[illegible] Mine	Shirley Basin
Mine Location	Shirley Basin, Wyoming	Shirley Basin, Wyoming	Shirley Basin, Wyoming
Flow rate, thousands gpd	[illegible]	[illegible]	[illegible]
pH	[illegible]	[illegible]	[illegible]
Alkalinity (as $CaCO_3$)	[illegible]	[illegible]	[illegible]
BOD, 5-day	[illegible]	[illegible]	[illegible]
COD	[illegible]	[illegible]	[illegible]
Total Solids	[illegible]	[illegible]	[illegible]
TDS	[illegible]	[illegible]	[illegible]
Total Suspended Solids	[illegible]	[illegible]	[illegible]
Total Volatile Solids	[illegible]	[illegible]	[illegible]
Ammonia (as N)	[illegible]	[illegible]	[illegible]
Kjeldahl Nitrogen	[illegible]	[illegible]	[illegible]
Nitrate (as N)	[illegible]	[illegible]	[illegible]
Phosphorus Total as P	[illegible]	[illegible]	[illegible]
Alpha-Total[c]	[illegible]	[illegible]	-
Beta Total[c]	[illegible]	[illegible]	-
Gamma Total[c]	no data	no data	-
U_3O_8	--	--	[illegible]

BOD = biochemical oxygen demand
$CaCO_3$ = calcium carbonate
COD = chemical oxygen demand
gpd = gallons per day
pH = acidity
TDS = total dissolved solids
U_3O_8 = yellowcake
< = is less than

[a] Composition data given in milligrams per liter unless otherwise specified.

[b] As reported in Corps of Engineers Discharge Permit Applications.

[c] In 10^{-9} curies per milliliter.

TABLE 9-25: WASTEWATER TREATMENT CHARACTERISTICS OF COMMUNITIES AFFECTED BY ENERGY DEVELOPMENT AT GILLETTE[a]

	Gillette	Casper
Type of Treatment	Extended Aeration	Adding secondary treatment to existing facility
Design Load	1.2 MMgpd (1.6 with modification)	10 MMgpd
Current Load	1.3 MMgpd	7 MMgpd
Future Plans	Powder River Areawide Planning Organization in Sheridan doing 208[b] planning; Step 1 of 201 is being done[c]	None at present

MMgpd = million gallons per day

[a] Water Quality Division of Department of Environmental Quality.

[b] Refers to Federal Water Pollution Control Amendments of 1972, § 208, 33 U.S.C.A. § 1288 (Supp. 1976), which encourages areawide waste treatment management.

[c] Refers to Federal Water Pollution Control Act Amendments of 1972, § 201, 33 U.S.C.A. § 1281 (Supp. 1976), which provides grants for construction of treatment works.

indicated in Table 9-25. Increases in wastewater resulting from energy development-induced population increases are portioned as shown in Table 9-26.

TABLE 9-26: EXPECTED INCREASES IN WASTEWATER FLOWS

Increased Flow Above 1975 Level (million gallons per day)		
Year	Gillette	Casper
1980	1	0.20
1990	1.9	0.63
2000	3.1	0.89

New wastewater treatment facilities adequate to meet the demands generated by these hypothetical developments and the associated population increases should be planned for Gillette by 1980. These facilities must use the "best practicable" waste treatment technology to conform to 1983 standards and must allow for recycling or zero discharge of pollutants (ZDP) to meet 1985 goals.[1] The 1985 goal could be met by using effluents from the waste treatment facility for industrial process make-up water or for irrigating local farmland. The energy development postulated in this scenario should not require any increase in wastewater treatment capacity for Casper.

9.3.5 Impacts

A. Impacts to 1980

The gas wells and the coal mine for rail transport will be constructed and in operation by 1980.

1. Surface Mine and Gas Wells

The surface coal mine may have several disturbing effects on the local Fort Union Formation aquifers. The coal mine will probably intersect either perched or water-table aquifers and disrupt aquifer flow patterns. If the mine is below the water table (the coal seams are aquifers in parts of the Fort Union Formation), mine dewatering will be necessary, and depletion of the aquifers will result. Discharges from mine dewatering probably will not exceed 500 gpm. Local springs and seeps on hillsides may dry up, and water levels in local wells may be lowered. Additionally, the base flow of streams in the area may be reduced. To comply with the zero-discharge provisions of current legislation, water from dewatering will be used for dust control and washing or will be reinjected in Fort Union aquifers an adequate distance down-gradient to prevent recycling of water to the mine. Thus, the loss to the aquifers will only be local. After the coal slurry pipeline begins operation in 1985, reinjection can be discontinued, and the water from dewatering can be piped to the slurry preparation plant for use as process water.

Depending on the composition of the overburden, weathering and oxidation of the spoil material may result in the release of contaminants. Both natural precipitation and water added for revegetation may pick up the contaminants and transport them into local aquifers. Aquifers in the immediate mine area will be affected the most. Aquifers in coal beds that are mined will be destroyed, and aquifers in the overburden will experience large changes in such properties as porosity and permeability. No alluvial aquifers are close enough to the mine to be affected by mining operations.

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[1] Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

Prior to 1980, revegetation will not have been initiated. As the quantity of trapped runoff water should be less than mine requirements for dust suppression, it will be used in conjunction with water from dewatering operations for dust suppression.

Surface-water drainage patterns will be affected by mine excavations, some of which will trap runoff. Unless these mines are pumped out regularly, some of the impounded water may eventually percolate into the groundwater system but should not produce any significant impacts. Losses in runoff due to mine excavations are not expected to be significant locally because area streams are ephemeral and runoff flow would quickly dry up in any case.

The gas wells will have little or no impact on local surface-water or groundwater systems, provided that proper well drilling and completion practices are used.

B. Municipal Facilities

The increase in population associated with the Gillette scenario will require an additional 3,190 acre-ft/yr of water by 1980 (see Table 9-22). This additional water will be taken either from local aquifers in the Fort Union Formation or from the Madison aquifer in the vicinity of Sundance. A well or well field capable of producing about 870 gpm will be required. This well represents a significant withdrawal, especially from the local Fort Union aquifers. Some of the population increase will take place in rural areas, rather than in Gillette. The increased withdrawal of groundwater at individual homesites is not expected to be significant.

Contamination of local bedrock aquifers from septic tank systems associated with the homesites may pose a significant water quality problem where the housing and septic tank densities become great enough to exceed the natural renovation capacity of the substrate. The Gillette area has an expansive clay soil that is not especially desirable for septic tank drainage fields and may become clogged or overloaded.

The increased capacity requirement for wastewater treatment will be about 1 million gallons per day (MMgpd). This will necessitate construction of a new treatment facility at Gillette or expansion of the existing facility. Unless new facilities come on-line to meet these requirements, some surface-water pollution may result from overloads and/or bypasses.

B. Impacts to 1990

The coal mines and energy conversion facilities for the slurry pipeline, the 3,000-megawatt electric power plant, the Lurgi high-Btu (British thermal unit) gasification plant, and the uranium mine and processing mill will be in operation by 1985.

1. Surface Mines and Gas Wells

The three coal mines and one uranium mine that will become operational between 1980 and 1990 will have impacts similar to those outlined in the preceding section. Perched aquifers or water-table aquifers in the Fort Union and Wasatch Formations may be intersected during mining operations. Where mine dewatering is necessary, aquifer depletion will be accentuated. Where mining takes place near streams, aquifers in the stream alluvium may be disturbed or destroyed by mining operations. If improper reclamation practices are used, weathering of overburden may result in the release of trace elements and other dissolved salts.

Surface-water impacts from the additional mines that will be opened during this period will have the same general impacts as stated earlier for the export coal mine. The uranium mine will also operate in a similar manner. Water supply requirements for dust control and revegetation will be met with water from trapped runoff and mine dewatering activities.

The gas wells should continue to have little or no impact on surface-water or groundwater systems.

2. Energy Conversion Facilities

Construction activities will increase greatly during this time period causing an increase in construction-related impacts such as removal of vegetation and disturbance of the soil.

The plants in operation by 1990 will probably not significantly affect the quantity of recharge to the shallow bedrock aquifers or the alluvial aquifers in the scenario area. As a result of either the failure or inadequacy of pond liners, on-site holding ponds may leak pollutants to local aquifers.

The uranium processing plant will obtain its process water from the Madison aquifer in the vicinity of Sundance. As noted earlier, 1,350 acre-ft/yr (about 800 gpm) will be used by the mill. This quantity of water will contribute to the depletion of the Madison aquifer.

The impact of the energy conversion facilities on distant surface waters will be larger than the impact on local groundwaters. Approximately 49,800 acre-ft/yr of water will be withdrawn from the Yellowstone River at Miles City for power generation and Lurgi gasification (see Table 9-30). The coal slurry pipeline will take about 18,400 acre-ft/yr from the North Platte. Since Gillette and the coal slurry facility are outside the Yellowstone River Basin, Wyoming cannot transfer Yellowstone River water to the facility without the consent of Montana and North Dakota. In any case, Wyoming can only use water that has been allocated to it by the Yellowstone Compact. Agreements will have to be made for Wyoming to remove water from the Yellowstone River in Montana.

The Yellowstone River at Miles City has an average yield of 8,166,510 acre-ft/yr. Withdrawal for the scenario energy facilities will not be a significant part of this flow. The minimum flow of record is 721,602 acre-ft/yr (996 cubic feet per second [cfs]). The average withdrawal (68 cfs) is equivalent to 7 percent of this minimum flow (see Table 9-30). As each of the facilities will have on-site reservoirs, withdrawals could be reduced during low-flow periods and the plants would draw from the reservoirs.

The minimum flow of record for the North Platte River near Glenrock (about 20 miles upstream from Douglas) is about 130,000 acre-ft/yr (176 cfs). The withdrawal of 18,400 acre-ft/yr (about 25 cfs) is approximately 14 percent of this low-flow value. An on-site reservoir will be used in low-flow periods to decrease or alleviate any degradation of in-stream needs.

The uranium mine and facilities will use local groundwater and are not expected to have a significant impact on surface water.

About 91,000 tons of solid wastes in the form of processing tailings will be produced by the uranium mill.[1] These tailings will be disposed of in tailings ponds that will also be used for the disposal of liquid and solid chemical and radiological wastes.[2] These wastes may pose a particularly large hazard to local aquifers should the tailings ponds leak. The degree of the hazard depends on the chemistry and radiology of the tailings and other wastes deposited in the ponds. The effectiveness of any pond liners provided will also strongly influence the degree of hazard.

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[1] U.S., Atomic Energy Commission, Directorate of Licensing, Fuels and Materials, *Environmental Survey of the Uranium Fuel Cycle*, WASH-1248. Washington, D.C.: Atomic Energy Commission, 1974, p. B-2.

[2] U.S., Department of the Interior, Bureau of Land Management, et al. *Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming*, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

No significant impact on surface water is expected of other plant effluents because discharge technology that meets the goals of the Federal Water Pollution Control Act Amendments of 1972 will be used.

3. Municipal Facilities

During the 1980-1990 period, the municipal requirements for water at Gillette will increase to 5,110 acre-ft/yr. This increased withdrawal, which is equivalent to about 3,170 gpm, presents a significant possibility for aquifer depletion from either the local well field or the Madison aquifer near Sundance. Because both Gillette and Casper are projected to use groundwater as a source for municipal needs, there will be no major impacts on local surface water hydrology as a result of withdrawals.

Increased capacity requirements for both water supply and wastewater capacities will be needed. Both cities may be able to sell effluent for reclamation or irrigation and thus satisfy the requirements for SDP.

Runoff will be increased by the expansion of existing towns, and some lowering of the water quality in nearby streams is expected from this.

The potential for aquifer pollution from increased septic tank use in rural areas will be similar to that described for the preceding decade but will be larger in magnitude.

C. Impacts to 2000

The coal mine and conversion facility for the Synthane plant will be operating by 1995. The Synthoil operation will be in production by 2000. The other energy conversion facilities, their associated mines, and the gas wells will continue operation during this decade.

1. Surface Mines and Gas Wells

Coal mines for the Synthane and Synthoil plants will have groundwater and surface-water impacts similar to those described earlier for coal mines for other scenario facilities. However, since the mines for the new facilities are smaller, the increase in impacts will be smaller than for the 1980-1990 period. The decrease in runoff as a result of mining activities will be less than 0.3 percent of the normal flow in the

Little Powder, Belle Fourche, or Cheyenne River Basins, and this reduction is not expected to be significant.

As the mines continue to operate, reclamation efforts will increase and larger water requirements must be satisfied by the use of water from mine dewatering and from wastewater treatment plant effluent at Gillette (see Table 9-21).

The gas wells should continue to have very little impact on surface-water or groundwater systems.

2. Energy Conversion Facilities

Water requirements for the Gillette scenario taken from the Yellowstone River will increase to about 59,600 acre-ft/yr in the 1990-2000 decade. At this level, the average withdrawal (82 cfs) is equivalent to about 8 percent of the minimum recorded historical flow (996 cfs). Water requirements for the North Platte will increase to about 37,800 acre-ft/yr or an average withdrawal of 52 cfs. This withdrawal is about 30 percent of the historical low flow of record (176 cfs). Water could be released into the North Platte from upstream reservoirs (such as the Pathfinder Reservoir or Seminoe Reservoir) to decrease the deleterious effect of these withdrawals if the water was available. Alternatively, water could be conveyed from the Green River to the North Platte to augment flows or to supply water to the facilities (see Figure 9-5). The impact of these withdrawals on the North Platte River during low-flow periods could be significant both in terms of flow depletion and from salt-concentrating effects. Alternate surface sources (such as a pipeline from Lake Oahe on the Upper Missouri River in South Dakota) or the use of groundwater to meet part of the needs may be necessary.

The Synthane and Synthoil conversion facilities will have the same type of pollution prevention systems as the previous energy facilities. These include the discharge of all effluents into clay-lined, on-site evaporative holding ponds to prevent contamination of local surface-water or groundwater systems. Runoff retention facilities will also be used.

3. Municipal Facilities

Municipal requirements for water will increase to 8,450 acre-ft/yr at Gillette and 2,000 acre-ft/yr at Casper due to the population increases from the energy conversion facilities. This increased withdrawal will lower groundwater levels, especially in the shallow aquifers in the Gillette area and the Madison aquifer near Sundance. To meet these water needs, either the well field in the vicinity of Sundance could be expanded or surface-water pipelines could be used to import water.

Wastewater treatment facilities at Gillette must be expanded to accommodate the additional needs (see Table 9-25). Effluent will continue to be used for reclamation or irrigation and thereby satisfy the requirements for ZDP by 1985.

Runoff from urban expansion will continue to increase resulting in further lowering of the water quality in nearby streams.

The potential for aquifer pollution from increased use of septic tanks by rural populations will increase as in previous decades.

D. Impacts after 2000

The mines will continue to operate with the same impacts as stated in the 1990-2000 decade until they are exhausted. Although many areas will be reclaimed and revegetated after the mines and their associated energy conversion facilities are decommissioned, irrigation of the areas will cease, some vegetation will be lost, and erosion will increase. After the mines are shut down, re-contoured, and revegetated, disruption of shallow aquifer systems will continue and surface flows will continue to be modified both in volume and quality.

After the energy conversion facilities are shut down, the berms around the ponds will probably lose their protective vegetation and erode, eventually resulting in breaches in the berms. When this happens, the materials within the pond site will erode and enter the surface-water system or percolate into the groundwater aquifers. The low precipitation in the scenario area will be a retarding factor in the transport of these materials.

Population levels will remain stable at least until the mines and associated energy conversion technologies are decommissioned. Thus, groundwater depletions will continue, and there will be a reduction in the quality of surface-water resources in the vicinity of Gillette and Casper due to runoff from the population increases. The amount of water in any surface-water sources used to supply municipal needs will also be reduced.

After the facilities are decommissioned, the towns of Gillette and Casper will remain but populations will decline.

9.3.6 Summary of Water Impacts

The water requirements for the postulated energy facilities total as much as 105,620 acre-ft/yr, including water needs for mine revegetation (see Tables 9-20 and 9-21). There are insufficient groundwater or surface-water resources in the immediate scenario area, and supplies must be imported by pipeline from such sources as the Yellowstone River and its tributaries (Clarks

Fork, Bighorn, Tongue, and Powder), Belle Fourche River, Green River, North Platte River, and Lake Oahe on the Upper Missouri River in South Dakota. The cost for this water will vary with the distance from the facility site. Before these sources can be used for energy development, legal restrictions from several compacts need to be lifted. Stream-flow withdrawals will have some effect on downstream salt concentrations. Since in-stream flow needs have not been established for all stream segments, this impact cannot be evaluated.

A potential long-term groundwater pollution problem is pond leakage. Pond liners should forestall this problem during the life of the plants, but the materials are likely to eventually leak through the liners and into the soil and groundwater.

Another possible impact that would follow the cessation of maintenance activities is the eventual destruction of berms containing salts, ash, trace materials, sanitary sludge, and scrubber sludge. If concentrations of these materials enter surface waters, both local biota and downstream water uses might be affected.

Gillette will face a significant impact in terms of providing adequate water supplies, municipal water treatment, and wastewater treatment facilities for the large influx of people expected during the scenario period. Gillette will need an additional 8,450 acre-ft/yr of water and must expand its wastewater treatment facility from a current capacity of 1.6 MMgpd to a capacity of 4.7 MMgpd by the year 2000 due to population increases from energy development (see Tables 9-22, 9-24, and 9-25). The water supply requirements of Gillette may contribute to depletion of local aquifers and the Madison aquifer.

Population increases in rural areas could cause deterioration of water quality in local aquifers from septic tanks.

Identification and description of several water impacts has been limited by available information. Missing data includes detailed information about process streams (needed to identify the composition of discharges to settling ponds) and about the rate of movement of toxic materials through pond liners (needed to estimate the portions that might reach shallow aquifers). More quantitative information will be sought during the remainder of the project so that these potential impacts can be evaluated.

9.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

9.4.1 Introduction

All the hypothetical developments in the Gillette scenario will occur in Campbell County in northeast Wyoming. This area experienced an oil and gas boom in the 1960's, followed by a population decline in the latter part of that decade. The current coal boom began in the early 1970's, and, the area's population has been growing steadily since then. In 1970, the population was twice that of 1960. With the hypothetical development included in this scenario, the population will continue to increase but at an accelerated rate. Most of the social, economic, and political impacts in the area will be related to population growth.

9.4.2 Existing Conditions

Campbell County has an area of 3 million acres. In 1974, its population was 12,000 by U.S. Census Bureau estimates, giving it a population density of 2.7 persons per square mile. Local estimates run as high as 17,000 for 1975. More than 80 percent of the population is centered in the only incorporated city, Gillette, which is the county seat. Since much of the population growth has occurred as a consequence of energy development, the population is disproportionately young and male.

Table 9-27 gives the employment distributions in Gillette during 1970 and in Campbell County during 1970 and 1975. As shown, construction, mining, and services are the major employers. Gillette also receives some economic benefit from hunters and tourists enroute to Devil's Tower National monument, the Black Hills, and Bighorn National Forest. Due to its location on Interstate 90, Gillette also serves some visitors to Yellowstone and Grand Teton National Parks.

Campbell County is governed by a board of three county commissioners elected at large for 4-year terms. The incumbents currently are all ranchers, indicating that long-time residents of the area have not been displaced by newcomers as might be expected with rapid growth.

The county provides few services by itself, in part because they are provided by the state (social and health services) or by the city and county jointly under the Joint Powers Act.[1] The school system is countywide, and fire protection and airport services are provided cooperatively by the city and county.

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[1] This act gives county and/or city governments the powers of both governments when they work together. For a description of this legislation, see Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 70-71.

TABLE 9-27: EMPLOYMENT DISTRIBUTION BY INDUSTRY FOR 1970 AND 1975

Industry	Gillette 1970	Campbell County 1970	Campbell County 1975	
	Number	Number	Number	Percent
Agriculture	1,017	601	579	8.4
Mining		1,323	1,406	20.3
Construction	221	268	1,604	23.1
Manufacturing	86	156	168[a]	2.4
Transportation	167	359	457	6.6
Communication and Utilities	44	96	175	2.5
Wholesale Trade		129	164	2.4
Retail Trade	610	706	898[b]	13
Finance, Insurance, and Real Estate	584	162	206	3
Services		907	1,154[c]	16.6
Public Administration	60	96	122	1.8
Total	2,799	4,803	6,933	100.0

Source: 1970: U.S., Department of the Census, Bureau of the Census. Census of Population: 1970; General Social and Economic Characteristics. Washington, D.C.: Government Printing Office, 1971.
1975: Estimated from data of Water Resources Research Institute, University of Wyoming.

[a] Mostly non-electric machinery.

[b] Mostly motor vehicles and service stations.

[c] To a large extent in public schools.

Currently under way is a joint effort to obtain funds from the Wyoming Community Development Authority to drill new water wells for the city.[1]

The city and county also cooperate in planning, animal control, park maintenance, and snow removal. As noted earlier, the county now provides about one-third of the support for the Gillette Department of Planning and Development, which functions in planning, zoning administration, city engineering, and building inspection. The staff consists of a planner, assistant planner, planning intern, city engineer, and several building inspectors.

Gillette is governed by a part-time mayor and six councilmen who are elected for 4-year terms. The city also has a full-time city administrator.

In addition to those services provided jointly with the county, the city provides its residents sewer, garbage, and electrical services. The electrical utility was recently expanded, but the city's application to the Economic Development Administration for $2 million to fund the extension and improvement of its sewage treatment facilities has been denied. The sewer system has recently been expanded through loans from the Wyoming Farm Loan Board.

The single countywide school district has met the needs of a growing population. In Gillette, two new elementary schools and a junior high school have been built, and two existing elementary schools have been enlarged. In large part, education problems have been minimal because the rate of population growth has been relatively steady and because the county's tax base has expanded with energy development.

In addition to the help provided by the state under the programs mentioned above, Gillette receives assistance from the Gillette Human Services Project, staffed by recent graduates of the University of Wyoming. This program (funded by the Economic Development Administration, state revenue sharing funds, and the Campbell County Children's Center) provides research assistance for finding solutions to growth-related problems and also provides extra manpower to human service agencies in impacted communities.[1]

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[1] The Community Development Authority was established to loan money to communities and to provide additional financing capacity to lending institutions for low-interest loans. The state's coal impact tax, a severance tax, provides revenue to guarantee the loans.

9.4.3 Population Impacts

In this scenario, the principal initial impact of energy development on Gillette and northern Wyoming was from the workers associated with the construction of an export surface coal mine in 1975 and with gas drilling activities in 1976. The employment related to the eight scenario developments is summarized in Table 9-28. The cyclical nature of the construction activity is evident, but a long-term new energy workforce of over 10 thousand persons is expected by 2000.[2] Overall population changes are based on the annual energy employment (for both construction and operation) and are estimated by means of an economic base model, the employment data in Table 9-28, and two sets of time-dependent multipliers (Table 9-29). The population estimates shown in Table 9-30 and Figure 9-6 were distributed among Gillette, the remainder of Campbell County, and Casper. No new population clusters in Campbell County are explicitly considered here, although scattered settlement is becoming more common. For example, Atlantic Richfield is providing housing at the town of Wright (near Reno Junction), about 40 miles south of Gillette. Note that the population impacts would differ significantly for a different construction schedule than that analyzed here.

The population of Campbell County will increase nearly six-fold to 70,100 by the year 2000 given the energy development proposed in the Gillette scenario. Most of this growth will occur in and near Gillette, where the area will attain a population of nearly 65,000 by 2000. Casper will achieve a population of over 50,000 as a result of the scenario development and will grow even larger if other extensive developments take place in eastern and central Wyoming. The size of the facilities in this scenario result in somewhat larger population estimates for

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[1] See Uhlmann, Julie M. *Gillette Human Services Project, Annual Report, August 31, 1976*. Laramie, Wyo.: University of Wyoming, Wyoming Human Services Project, 1976.

[2] Based on projections using Bechtel's energy supply planning model. See Carasso, M., et al. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 9-20: NEW EMPLOYMENT IN ENERGY DEVELOPMENT IN CAMPBELL COUNTY, 1975-2000

Year	Construction	Operation	Total
1975	110	0	0
1976	780	0	780
1977	1,340	0	1,340
1978	2,370	880	3,250
1979	2,420	1,140	3,560
1980	1,080	2,450	3,530
1981	2,780	2,450	5,230
1982	5,800	2,680	8,480
1983	8,130	3,890	12,020
1984	5,480	5,080	10,560
1985	740	5,860	6,600
1986	0	5,860	5,860
1987	0	5,860	5,860
1988	0	5,860	5,860
1989	0	5,860	5,860
1990	60	5,860	5,920
1991	760	5,860	6,620
1992	2,830	5,860	8,690
1993	4,890	6,050	10,940
1994	3,380	6,640	10,020
1995	2,280	6,830	9,110
1996	4,490	6,830	11,320
1997	5,210	6,830	12,040
1998	3,710	7,110	10,820
1999	1,250	8,580	9,830
2000	0	10,320	10,320

Source: Carasso, M., *et al.* *The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 9-29: EMPLOYMENT AND POPULATION MULTIPLIERS FOR GILLETTE SCENARIO POPULATION ESTIMATES

Service/Basic Multipliers[a]		
Year	Construction	Operation
1975	0.4	
1976	0.4	
1977	0.5	
1978	0.6	0.8
1979	0.8	0.8
1980	0.8	0.9
1981	0.7	1
1982	0.7	1
1983	0.7	1.1
1984	0.7	1.2
and after	0.7	1.2
Population/Employee Multipliers[b]		
Construction	2.05	
Operation	3.30	
Services	3	

[a] These values were selected after examining several studies of the northeastern Wyoming area, including Hayen, Roger L., and Gary L. Watts, A Description of Potential Socio-economic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975; Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group, Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains, Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974; U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974; Wyoming, Department of Economic Planning and Development, Coal and Uranium Development of the Powder River Basin: An Impact Analysis. Cheyenne, Wyo.: Wyoming, Department of Economic Planning and Development, 1974; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; Watson, Roger A., and Jeanette R. Studer, Energy Resource Development in Wyoming's Powder River Basin: An Assessment of Potential Social and Economic Impacts. Denver, Colo.: Northern Great Plains Resources Program, 1974.

[b] Adapted from Mountain West Research, Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

TABLE 9-30: POPULATION ESTIMATES FOR CAMPBELL COUNTY, GILLETTE, AND CASPER, 1974-2000[a]

Year	Campbell County[b]	Gillette	Casper
1975	12,090[c]	10,000	40,000
1980	25,400	22,500	42,200
1985	44,000	40,200	45,000
1990	43,700	39,950	46,750
1995	58,150	53,600	48,650
2000	70,100	65,100	50,600

[a] Estimates incorporate an annual natural increase of 0.8 percent through 1990 and 0.5 percent from 1991-2000. Some yearly peaks, caused by the employment needs in Table 9-27, are missed in the above presentation. Given the assumptions of the scenario, the estimates of population increase should be considered to have a ± 20-percent range associated with them.

[b] Campbell County was assumed to be the location for 100 percent of all energy development employment, with 90 percent occurring in or near Gillette alone. Ninety percent of service population was assumed to locate in Gillette with the remaining 10 percent at Casper.

[c] U.S., Department of Commerce, Bureau of the Census. "Estimates of the Population of Wyoming Counties: July 1, 1973 and July 1, 1974." *Current Population Reports*, Series P-26, No. 103 (April 1975), p. 3. The local estimate for 1975 is closer to 17,000 (Mike Enzi, personal communication) and will be incorporated in future reports.

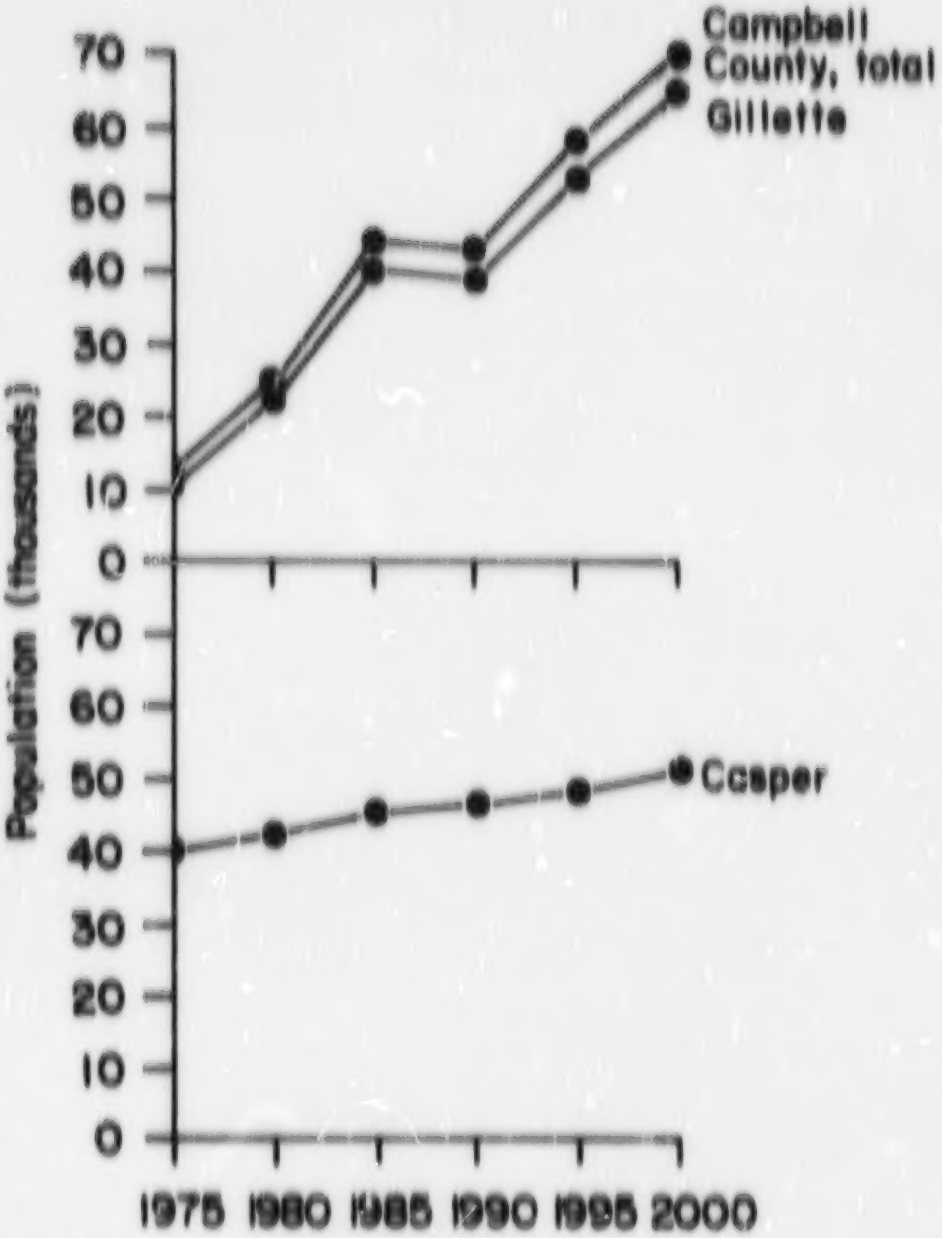

FIGURE 9-6: POPULATION ESTIMATES FOR CAMPBELL COUNTY, GILLETTE, AND CASPER, 1975-2000

Campbell County than previous studies have found; thus, the population growth discussed in this section may overestimate future conditions.[1]

Age-sex distributions of the projected population in Campbell County provide an indication of housing and educational needs in the area. Using 1970 age distributions, new employment in the county was assumed to correspond to data reported in the *Construction Worker Profile*.[2]

The marital status of construction workers and age distribution of their children were also assumed to be distributed according to recent empirical findings in the West. The resulting age-sex distributions (Table 9-31) show increases in the 25-34 age group through 1985 and in the 35-64 age groups after 1985. During intensive construction periods, the relative proportion of males to females is especially high, although males comprise at least 51.5 percent of the population throughout the 25-year period.

9.4.4 Housing and School Impacts

Housing demand and school enrollment can be estimated from the information presented in Tables 9-30 and 9-31 and by assuming that the 6-13 age group constitutes elementary school enrollment and that the 14-16 age group is secondary school enrollment (Table 9-32 and Figure 9-7). The development proposed by the scenario results in a 130-percent increase in the current number of households by 1980, rising to a total of 28,000 by the year 2000. At no time is the annual rate of growth in housing demand less than about 5 percent.

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[1] See, for example, U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 149-175; and Wyoming, Department of Economic Planning and Development. *Coal and Uranium Development of the Powder River Basin--An Impact Analysis*. Cheyenne, Wyo.: Wyoming, Department of Economic Planning and Development, 1974, pp. 51-75.

[2] See Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

TABLE 9-31: PROJECTED AGE-SEX DISTRIBUTIONS OF CAMPBELL COUNTY, 1975-2000[a]

Age	1975	1980	1985	1990	1995	2000
Female						
65-over	.023	.012	.009	.010	.011	.015
55-64	.024	.018	.014	.019	.126	.139
35-54	.090	.083	.075	.121	.123	.129
25-34	.076	.118	.132	.114	.106	.116
20-24	.046	.048	.048	.041	.051	.043
17-19	.025	.024	.023	.033	.031	.025
14-16	.031	.024	.020	.034	.025	.027
6-13	.094	.076	.067	.071	.063	.063
0-5	.071	.071	.074	.039	.040	.026
Total	.482	.478	.485	.485	.480	.483
Male						
65-over	.022	.012	.008	.011	.013	.017
55-64	.029	.021	.016	.023	.030	.042
35-54	.120	.104	.090	.142	.143	.146
25-34	.085	.136	.145	.122	.118	.126
20-24	.041	.050	.050	.041	.058	.044
17-19	.023	.024	.024	.032	.021	.025
14-16	.032	.025	.028	.036	.025	.027
6-13	.097	.077	.083	.071	.065	.063
0-5	.069	.073	.074	.039	.040	.036
Total	.517	.52[illegible]	.51[illegible]	.515	.519	.516

[a] Total may not sum to 1.0 because of rounding.

TABLE 9-32: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN CAMPBELL COUNTY, 1975-2000

Year	Number of Households	Number of Elementary School Children[a]	Number of Secondary School Children[b]
1975	3,600[c]	2,300[c]	760[c]
1980	6,800	3,900	1,250
1985	14,550	7,250	2,450
1990	16,200	6,200	2,950
1995	22,600	7,550	2,900
2000	26,000	6,800	3,600

[a] Ages 6-13.

[b] Ages 14-16.

[c] Estimates.

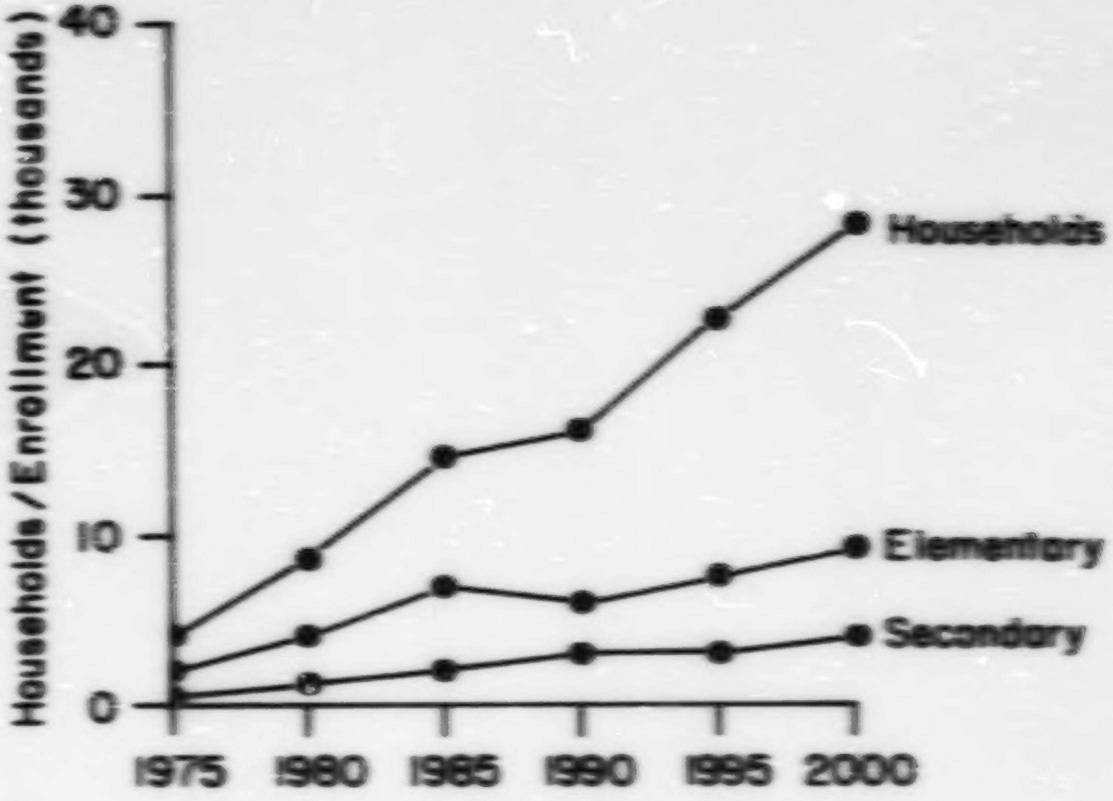

FIGURE 9-7: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY AND SECONDARY SCHOOL CHILDREN IN CAMPBELL COUNTY, 1975-2000

TABLE 9-33: DISTRIBUTION OF NEW HOUSING BY TYPE OF DWELLING[a]

Period	Mobile Home	Single Family	Multi-Family	Other[b]
1975-1980	2,650	950	600	800
1980-1985	3,050	1,100	700	920
1985-1990	875	300	200	260
1990-1995	3,400	1,200	770	1,020
1995-2000	2,860	1,020	650	860

[a] Compiled from Table 4 and data in Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 103.

[b] e.g., campers and recreational vehicles parked on recreational or private land.

Approximately one-third of Gillette's current housing is mobile homes,[1] a pattern that is expected to continue as shown in Table 9-33. (The figures in Table 9-33 are perhaps overly optimistic about the extent to which single and multi-family housing construction will occur.) An average of about one thousand new single-family homes should easily be filled in Campbell County during each 5-year period through 2000.

School enrollment impacts will change over time; elementary school enrollment in the scenario is expected to increase nearly 70 percent by 1980 and to reach 8,800 by 2000. This upward trend is broken only by a slight decline between 1985 and 1990, which reflects the absence of construction activity. High school enrollment shows a similar trend, continuing to increase except for a slight drop between 1990 and 1995. At an average class size of 21 students, 100 new classrooms will be needed by 1980 at

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[1] Mountain Plains Federal Regional Council. Compilation of New Data on Energy Impacted Communities including Characteristics, Conditions, Resources and Structures. Denver, Colo.: Mountain Plains Federal Regional Council, 1976.

TABLE 9-34: SCHOOL DISTRICT FINANCE NEEDS FOR CAMPBELL COUNTY, 1975-2000[a]

Year	Enrollment Increase Over 1975	Classrooms (21 students per room)	Capital Expenditures Increase (millions of dollars)[b]	Operating Expenditures Increase (millions of dollars)[c]
1975[d]	3,060	150		6.05
1980	2,090	100	5.23	4.18
1985	6,640	316	16.60	13.28
1990	6,090	290	15.23	12.18
1995	7,390	352	18.48	14.78
2000	9,540	454	23.85	19.08

[a] These figures may be compared with Haven, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 24, 78, 87.

[b] An average of $2,500 per pupil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. *Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81*, A Report to the President's Commission on School Finance, Washington, D.C.: Government Printing Office, 1971, and inflated to 1975 dollars.

[c] An overall average of $2,000 per pupil was assumed.

[d] Basic data from Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee, *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII.* Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

a cost of approximately $5.25 million (Table 9-34). The school district's financial needs will probably triple by the end of the century, although there will be a brief period of overcapacity in the late 1980's.

9.4.5 Land-Use Impacts

Energy facilities involved in this scenario will occupy about 73 square miles in the Campbell County area. This amounts to about 1.5 percent of the county's area and excludes housing and other development-related land uses. The population

TABLE 9-35: LAND REQUIRED FOR POPULATION-RELATED DEVELOPMENT IN CAMPBELL COUNTY (in additional acres after 1975)[a]

Land-Use	1980	1985	1990	1995	2000
Residential	670	1,600	1,585	2,308	2,905
Streets	134	320	317	462	581
Commercial	16	38	38	55	70
Public and Community Facilities	42	99	98	143	180
Industry	67	160	159	231	291
Total (acres)	929	2,217	2,197	3,199	4,027
(square miles)	1.5	3.5	3.4	5.0	6.3
(square kilometers)	3.7	8.9	8.9	12.9	16.3

[a] Assumes: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; industrial land = 5 acres per 1,000 population. Adapted from THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 28-30.

expansion can be expected to occupy about 7 square miles (Table 9-35). Overall land development in the county should amount to less than 100 square miles, although successful reclamation as mining progresses would cut the estimates here by about 50 percent. Very little of the land in the county is cropland (about 4 percent); most of the land on and near the resource sites is currently used to graze cattle and sheep.[1] Little of this activity would be affected by mining, although 10 percent of the county will be within .5 mile of some transportation right-of-way, including rail, extra-high voltage transmission lines, and slurry pipelines.

In addition to the actual occupation of the land for residential, industrial, and governmental uses, other land can become greatly changed due to leisure time activities of residents. Already hunting and especially off-road vehicle traffic has taken place on private and public land. This potential impact is elaborated in the discussion of ecological impacts (Section 9.5).

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[1] U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture: Preliminary Report, Campbell County, Wyoming. Washington, D.C.: Government Printing Office, 1976.

TABLE 9-36: PROJECTED INCOME DISTRIBUTION FOR CAMPBELL COUNTY, 1975-2000 (in 1975 dollars)[a]

Year	Less Than 4,000	4,000 to 5,999	6,000 to 7,999	8,000 to 9,999	10,000 to 11,999	12,000 to 14,999	15,000 to 24,999	25,000 and Over	Median Household Income
1975	.061	.049	.038	.059	.066	.113	.377	.266	18,200
1980	.068	.035	.036	.063	.086	.120	.442	.171	17,580
1985	.051	.040	.037	.070	.094	.123	.446	.136	16,300
1990	.050	.045	.040	.073	.097	.127	.432	.130	16,390
1995	.053	.046	.038	.068	.097	.136	.445	.118	16,600
2000	.059	.047	.041	.075	.103	.139	.436	.113	16,100

[a] Data for 1975 are adapted from U.S., Department of Commerce, Bureau of the Census. *Household Income in 1969 for States, SMSA's, Cities and Counties: 1970*. Washington, D.C.: Government Printing Office, 1973, p. 37, and inflated to 1975 dollars. Income distributions for construction, operation, and service workers are from Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that new service workers' households have same income distribution as long-time residents and that "other newcomers" are operation employees.

9.4.6 Economic and Fiscal Impacts

A. Economic

The economy of Campbell County is now dominated by mining, agriculture, and construction (totaling 48 percent of total personal income). Conversely, services, local government, finance, insurance, and real estate employ less than state and national averages.[1] Gillette's economy has a significant contribution from out-of-state hunters. This mix should become somewhat less concentrated in energy-related sectors during the next 25 years as service-sector employment gradually increases to a more average level compared to state and national employment.

Primarily because of the change in industry mix, the countywide income distribution should gradually decline to $16,100 (1975 dollars) during the 1975-2000 period.[2] However, despite this 11.5-percent decline, the countywide average will still be above the current national average (Table 9-36 and Figure 9-8). The

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[1] U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." *Survey of Current Business*, Vol. 54 (May 1974, Part II), pp. 1-75.

[2] This projection does not include national trends, such as technological change, productivity gains, etc.

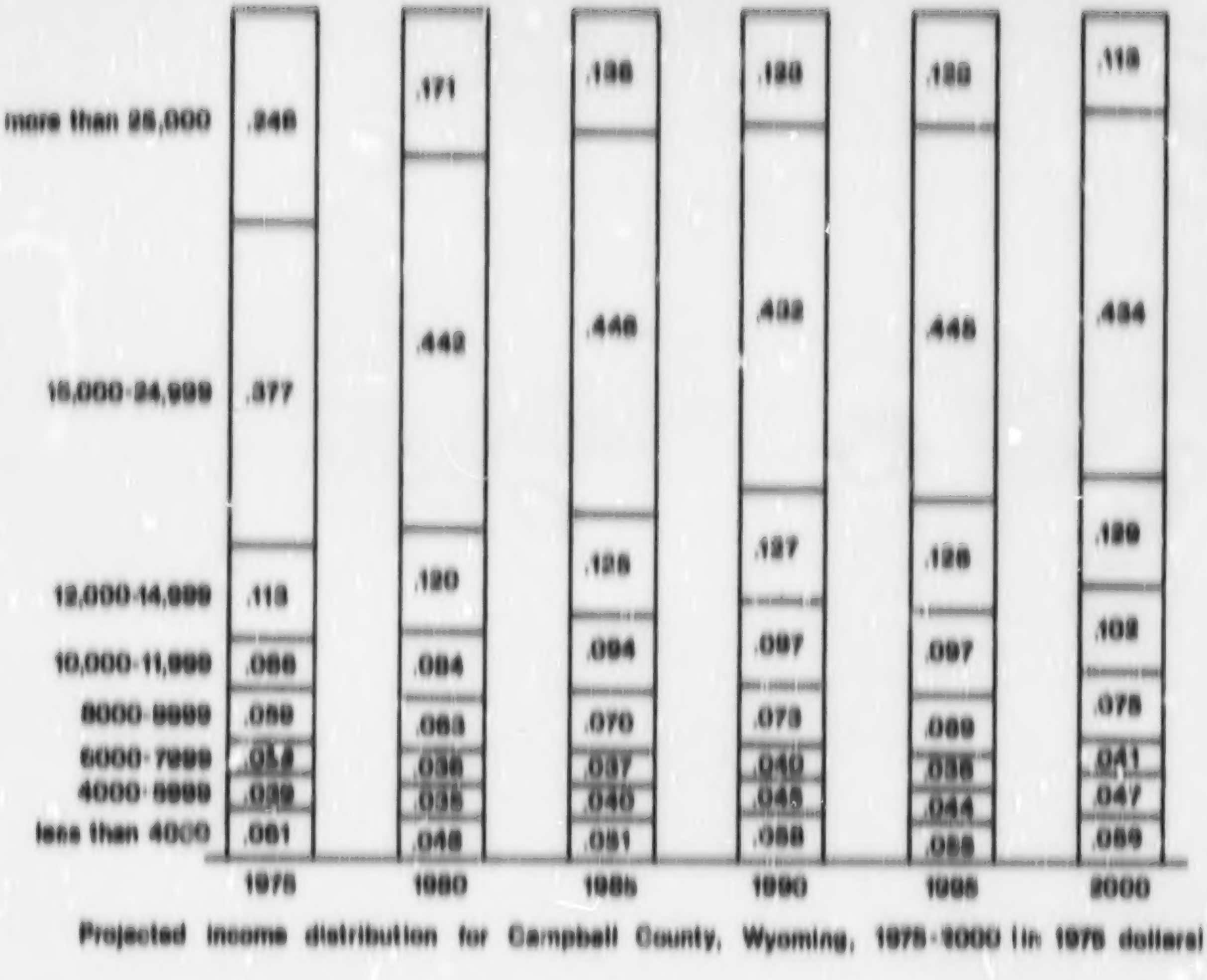

FIGURE 9-8: PROPORTIONAL PROJECTED INCOME DISTRIBUTION FOR CAMPBELL COUNTY, 1975-2000 (in 1975 dollars)

proportion of households in income categories between $8,000 and $15,000 will increase, while the proportion in the over $25,000 category will decrease. High school age boys are being attracted to energy-related employment and, as a consequence, high school girls are being employed in gas stations and other services. This pattern is likely to continue for some time.

The expected increase in the service sector will actually be caused by an anticipated expansion in local business activity. The rapid increase in the number of businesses in Gillette, which has tripled since 1968, should continue. Even if the rural population growth is greater than expected, Gillette will still benefit from retail activity because it is the only market center in the county. Casper, the nearest city comparable to Gillette, also will receive additional retail activity because of Campbell County's energy development.

To the extent that export mines are developed, rather than mines directly attached to conversion facilities, the local economy will experience less direct benefit. On the other hand, the smaller population would place smaller demands on public services.

Tourism is not likely to be greatly affected because, unlike many parts of the West, Gillette is not a particularly attractive place for tourism. Some traffic occurs because of Devil's Tower National Monument 60 miles east of town, but the area does not compare with the major national parks in the region as a tourist attraction. However, hunting of the large antelope, deer, and other animal populations is likely to increase substantially (within state licensing limits) as a result of the increased population (see Section 9.5).

B. Fiscal

Municipal services will be severely strained, especially early in the population expansion period.[1] An estimate of capital expenditure needs for Gillette emphasizes the importance of water and sewage facilities in rapid population growth areas (Table 9-37). In overall operating expenditures, per-capita costs tend to rise as a town's population increases; however, much of the increase can be attributed to capital expenditures and debt service.[2] Employing an average of $120 per capita, the

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[1] See Gillette, Wyoming, City of. Catalog of Public Investment Projects, 1976 to 1986. Gillette, Wyo.: City of Gillette, 1976.

[2] THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 9-37: PROJECTED NEW CAPITAL EXPENDITURES REQUIRED FOR PUBLIC SERVICES IN GILLETTE, 1975-2000 (millions of dollars)[a]

Period	Water and Sewage	Hospital	Airport	Other[b]	Total
1975-1980[c]	22.7	11		4	37.7
1980-1985[d]	31.2		7	7.9	46.1
1990-1995[e]	23.6	10		9.1	42.7
1995-2000[e]	20.2	5		5.2	30.4

[a] 1985-1990 is omitted because a slight decline in population (and therefore service demands) occurs during that period.

[b] Other includes parks and recreation, city-owned utilities, libraries, police and fire protection, administration, public works, and some street and road work. Sixty percent of the coal severance tax must be used for roads, providing perhaps some relief in that category. See Hayen, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 59.

[c] From Gillette, Wyoming, City of. *Catalog of Public Investment Projects, 1976 to 1986*. Gillette, Wyo.: City of Gillette, 1976.

[d] From Gillette, *Public Investment* plus increment for additional population expected for scenario development (40,200 versus 35,000). Increment computed from information in U.S. Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 321; THK Associates. *Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study*. Denver, Colo.: THK Associates, 1974, p. 30; Lindauer, R.L. *Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments*. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

[e] Computed from references in footnote d above.

TABLE 9-38: NECESSARY OPERATING EXPENDITURES OF GILLETTE

Year	1980-2000[a] (thousands of 1975 dollars)
1975[b]	2,514
1980	4,014
1985	6,139
1990	6,108
1995	7,746
2000	9,136

[a] Based on $120 per capita (1975 dollars) broken down roughly as follows: roads and streets (35 percent), health and hospitals (14 percent), police (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), administration (10 percent) and other (12 percent). See THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 41. The $120 average is probably low for Gillette.

[b] Source: Hayen, Roger L., and Gary L. Watts. A Description of Potential Socio-economic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 30. For detailed projections of short-term needs (through 1985), that source is particularly useful.

additional operating expenditures required of Gillette as a result of the scenario increase an average of 5.3 percent per year (compound) through 2000 (Table 9-38). The estimated operating expenditures are probably low (perhaps as much as 20 percent), but they indicate the increase in financial needs with a population increase. Adding these operating expenditures to the capital needs in Table 9-37 shows that Gillette will have problems in meeting population-related needs through 1985 and again after 1990. A major cause of these problems will be that energy development taking place outside Gillette's city limits will not provide the city with the tax revenues needed to fund the required municipal services.

The largest portion of new taxes will come from levies directly on the facilities, and the largest of these items will be the property tax. By the end of the century, the energy developments in our scenario will carry an assessed value of about $3 billion, or almost 10 times the total current 1975 assessment in Campbell County. Until the last few years of the scenario, the new values consist of roughly equal portions of facilities (assessed at 24 percent of invested value) and coal production (assessed at 100 percent of each year's extracted value). The final facility to be added, a 100,000 barrels per day coal liquefaction plant, is very capital intensive, bringing $3.9 billion of new property to the county or some 24 times as much as the value of the coal which annually supplies it (and comparable with the value of all other facilities in the scenario combined).

When the current mill levies--48.98 mills for schools (local and state programs) and 11.99 mills for other county purposes[1]--are applied to the energy facilities, new revenues would be generated as in Table 9-39. The major beneficiary of new property tax revenues would be education. More than $150 million would be added annually to school budgets if the current rates were maintained. However, as indicated in Table 9-34, the school will need only $19 million per year in additional operating expenditures to maintain current standards. Clearly, there would be considerable leeway for lowering the school mill levy.

Other revenues derived directly from energy facilities include severance taxes and royalties. The Impact Assistance Act[2] will collect 2 percent of the value of coal extracted until $120 million has been accumulated. The mines in our scenario will produce that much coal by 1990, so the tax which is collected statewide will probably terminate in the 1980's. Proceeds will be allocated by the Wyoming Farm Loan Board to impacted areas for building infrastructure, especially roads. Another tax of 1.5 percent will be collected permanently to establish the Mineral

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[1] U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 341.

[2] The act provides funds to mitigate impacts related to the development of coal, gas, shale oil, and other minerals.

TABLE 9-39: NEW PROPERTY TAX REVENUES, CAMPBELL COUNTY
(millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Value of facilities[a]	633	2,049	2,049	3,756	7,748
Value of coal production[b]	216	698	790	981	1,234
Value of residential development[c]	77	184	183	266	335
School revenue, Campbell[d]	19	70	74	95	155
Other revenue, Campbell[d]	4.6	17.1	18.2	23.3	38.1
Municipal revenue, Gillette[e]	.62	1.47	1.46	2.13	2.68
Value of residential development, Casper[c]	12.8	28.8	38.9	49.8	61.1
Property tax revenue, Casper[d]	.19	.42	.57	.73	.89

[a] Carasso, M., *et al.* *The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975.

[b] Scenario definition combined with SRI projections of price.

[c] Population projected as in text combined with assumption of $5,762 per capita (market value) for residential and commercial development. See Hayen, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 108.

[d] At current rates. See text.

[e] At assumed mill levy of 8 applied to residential and commercial development.

TABLE 9-40: SEVERANCE TAXES AND PUBLIC ROYALTIES
(millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Impact Assistance Act[a]	4.5	14	0	0	0
Mineral Trust Fund[b]	14	61	132	216	319
Interest on Trust Fund[a,c]	.7	3	6.6	10.8	16
State share of federal royalties[a,d]	6.1	19.6	22.2	27.6	34.7

[a] Annual rate.

[b] Accumulation.

[c] At 5 percent.

[d] Assuming 45 percent of coal under Federal lease.

Trust Fund.[1] Income from the fund will go to the state's general fund, but the principal will be used for loans to localities. Finally, the state will receive 50 percent of federal coal royalties. Under recent legislation, royalties have been targeted at one-eighth of the coal's value. (Approximately 45 percent of the coal in the scenario area is owned by the federal government.) The various mineral taxes and royalties are summarized in Table 9-40.

The other public revenue impacts in this scenario, sales taxes and utility fees, are population related. New sales tax revenues can be estimated on the basis of the incomes already projected. At each point in time, all the following factors are multiplied together: number of households, average income per household,[2] average propensity to buy taxable goods,[3] the sales

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[1] See Hayen, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 69-70.

[2] $17,600 in 1980, $16,910 in 1985 and thereafter.

[3] 56 percent of income in the Mountain States.

TABLE 9-41: ADDITIONAL POPULATION-RELATED TAXES AND FEES
(millions of 1975 dollars)

Source	1980	1985	1990	1995	2000
Retail sales, Campbell	49.3	101.8	117.6	178	229.2
Retail sales, Casper	8.2	15.9	25.1	33.4	41.7
Sales Tax Shares					
State	1.15	2.35	2.85	4.23	5.42
Campbell County	.25	.51	.59	.89	1.15
Gillette City	.25	.51	.59	.89	1.15
Casper and Natrona	.08	.16	.25	.33	.42
Total	1.72	3.53	4.28	6.34	8.13
Utility fees, Gillette[a]	1.96	4.74	4.70	6.06	8.65
Utility fees, Casper[a]	.35	.79	1.06	1.36	1.66

[a] At $157 per capita. See Hayen, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 118.

tax rate,[1] and the split between levels of government.[2] These factors are brought together in Table 9-41 along with an estimate of municipal utility fees.

All the revenue sources identified above can be regrouped by level of government, as in Table 9-42. Comparisons can then be readily made with the demands for new public expenditures (Tables 9-37 and 9-38). For Gillette to meet its expenditures, it must share costs with Campbell County or annex county land to add to the city tax base. (Intergovernmental financial relations are discussed further in Section 9.4.8.)

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[1] Three percent by the state, another 1 percent optional by county.

[2] Two-thirds to the state, roughly one-sixth each to county and city.

TABLE 9-42: NEW REVENUE FROM ENERGY DEVELOPMENT, BY LEVEL OF GOVERNMENT
(millions of 1975 dollars)

Jurisdiction	1980	1985	1990	1995	2000
Wyoming (state[a])	12.3	30	31.6	42.6	56.1
Campbell (county)	4.8	17.6	18.8	24.2	39.3
Gillette (city)	2.8	6.7	6.8	9.9	12.5
Casper (city and county)	.6	1.4	2.4	2.4	3

[a] Including amounts to be allocated to impact areas.

9.4.7 Social and Cultural Effects

Several major groups of people live in and around Gillette: ranchers, oil company employees, coal mining and related construction employees, and businessmen. The managerial-level oil company employees, some of them Gillette residents for 10 years, are able to take part in local affairs while the other newcomers largely are not.[1]

The social segregation has spatial results, particularly noticeable in the predominance of mobile home living among field workers and their families. One effect of a large increase in coal-related population is likely to be yet more mobile home neighborhoods spatially distinct from existing housing. Dissatisfaction with mobile home living can only increase as a result of the scenario analyzed here.[2] Further, child neglect and abuse appear to be a consequence of the migrant nature of construction families around Gillette.[3]

In public and private services, medical care is in particularly short supply. Only eight doctors served Gillette in 1974,

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[1] University of Montana, Institute for Social Science Research, A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 49-52, 75.

[2] Ibid.

[3] Richards, Bill. "Western Energy Rush Taking Toll Among Boom Area Children." Washington Post, December 13, 1976, pp. 1, 4.

TABLE 9-43: PHYSICIAN NEEDS IN CAMPBELL COUNTY, 1975-2000.

Year	Population	At Ratio of One Doctor per 900 People	At Ratio of One Doctor per 700 People
1975	12,000	13	17
1980	25,400	28	36
1985	44,000	49	63
1990	43,700	49	63
1995	58,150	65	83
2000	70,100	78	100

a ratio of about one physician to 900 people.[1] Gillette has had trouble attracting and keeping doctors, and as a consequence, newcomers sometimes have a hard time even getting appointments.[2] The need for new physicians (Table 9-43) will be as acute as the need for additional water and sewage treatment but is less likely to be ameliorated by local government policy. Physicians are highly mobile and attracted by both large urban areas (and their well-equipped hospitals) and pleasant outdoor amenities. For the latter reason, Sheridan seems to do better than Gillette and other similar-size towns at attracting physicians.[3] Company-supported health maintenance organizations or other group medical practice may be necessary to meet medical needs in Campbell County. However, the current trend toward family practice, rather than medical specialization, will help small cities such as Gillette.[1]

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[1] By comparison, Sheridan has 17 doctors, a ratio of one per 675 people; the national average is about one per 660 people. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII*. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2] University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 77-78; and U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 36-44.

[3] University of Montana. *Impact of Coal Development*.

The social unrest among the various groups in Gillette will exist until some stable pattern of social interaction takes precedence over the constant conflict between oldtimers and newcomers.[2] On a countywide scale, ranchers now dominate most local positions of power. This control is most threatened by the growth of urban Gillette, not by the mining and energy-related activity. The urbanization issue in Wyoming and much of the West is particularly contentious because of the desire to keep the small-town atmosphere, which is declining.[3]

The quality of life in Gillette will not be judged favorably by many residents during the course of this development. Water supply problems, medical service shortages, and the lack of street maintenance are only a few of Gillette's negative attributes that largely can be expected to continue.[4] On the positive side, employment opportunities are abundant in Gillette, the number and mix of retail goods and commercial services is expanding steadily, and a number of high-quality recreational areas are available within a few hours of the town.

The negative aspects of living in Gillette will not be reduced or eliminated easily. Financial strain on the community appears to be a major source of unfavorable opinion about life there. In addition, the integration of new residents into social groups and their participation in local affairs may be difficult and constitutes an important consideration for individuals.

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[1] Loan forgiveness programs also appear to be an important influence on rural and small-town location of physicians. See Coleman, Sinclair. *Physician Distribution and Rural Access to Medical Services*. R-1987-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

[2] University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974.

[3] University of Montana. *Impact of Coal Development*; and Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group. *Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains*. Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 37-73.

[4] Gillette, Wyoming, City of-Campbell County. *Citizen Policy Survey*. Gillette, Wyo.: City of Gillette-Campbell County, Department of Planning and Development, 1976.

9.4.8 Political and Governmental Impacts

Some of the social effects of energy development will be reflected in the political affairs and governmental administration of both Gillette and Campbell County. Immediate impacts on governmental administration will occur as localities demand expanded public services and as the sphere of public purpose is extended into quasi-public areas such as the provision of private housing and health care. Providing these services will require a concerted planning, coordination, and implementation effort on the part of all the parties-at-interest in the Gillette energy development area. Further, the changing nature of the population will strain the existing political balance, forcing accommodation of new attitudes and values in local decisions.

Wyoming, through the state legislature, has implemented a number of measures to reduce local fiscal impacts caused by energy-related growth.[1] The Wyoming Community Development Authority was created and authorized to provide loans to communities and to provide additional financing capacity to traditional lending institutions for low-interest housing loans. Severance tax revenues are used to back the Development Authority, thus providing a better bond rating for municipal loans by guaranteeing repayment. This Wyoming finance agency is unique because it has the power to make loans to both the public and the private sector to raise additional mortgage money. Gillette's ultimate fiscal status, as well as the status of other communities in the area, will depend significantly on actions taken by the Community Development Authority as it responds to various assistance requests.

Legislative provisions of the Coal Tax for Impact Assistance Act allow the Wyoming Farm Loan Board to disperse funds collected from the state severance tax. Grants are made to communities which have exhausted other reasonable means of financing sewer and water systems, streets, and road projects. Similarly, as a condition for issuing an industrial development permit, the Wyoming Industrial Information and Siting Act of 1975 provides authority to require an applicant to share in the financing of needed public facilities and services, including schools. Again, dispersion and enforcement actions by the state will be critical in determining whether Gillette receives the kind of immediate impact assistance required.

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[1] For a detailed review of Wyoming's legislative package dealing with the fiscal impacts of energy development, see Hayen, Roger L., and Gary L. Watts. *A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 57-74.

Energy development in the area will also lead to changes in Gillette's relationship with Campbell County. Public services, such as law enforcement, fire protection, and water supply, will require a concerted effort on the part of the city and Campbell County to upgrade and maintain adequate levels of performance. Although, as shown in the previous fiscal analysis, expenditures and revenues will be fairly equal between 1975 and 1990, Gillette will experience a deficit until 1983. This deficit will be at its largest, $1.2 million, in 1980. When compared to Gillette's 1975 budget of about $2.5 million, these data indicate the city will be faced with a deficit approximately 50 percent as large as current revenues. If capital costs are included, the deficit in 1980 would be about $3.5 million instead of $1.2 million. A factor mitigating this fiscal imbalance could be redistribution of tax revenues from the county since its revenues are expected to expand dramatically after 1980, nearly tripling Gillette's expenditures by 1985. With redistribution to Gillette, the total operating and capital expenditures required in this scenario could easily be met after 1980, but such action requires uncommon fiscal cooperation between both jurisdictions.

As noted earlier, the city and county cooperate on planning, as personified by a city-county planner on the county payroll.[1] Along with Wyoming's Joint Powers Act, which authorizes counties to join with other local governments in financing facilities, planning for future growth of Gillette appears to be reasonably enabled. However, there is no means for requiring that the Joint Powers Act be involved, leaving the vast majority of Gillette's financing problems to the city. In addition, the city-county planner's recommendations need not be, and often are not, approved by the Board of County Commissioners. Another complication to planning results from the fact that the Industrial Development Information and Siting Act applies to facilities with construction costs greater than $50 million. Several of the currently planned operations are valued slightly below that limit[2] in what is perhaps an attempt to avoid the effects of the law. These and similar specific problems greatly limit Gillette's efforts to plan adequately for future growth.[1]

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[1] During fiscal year 1975, the total county contribution was $55,000 of the $150,000 budget of the Department of Planning and Development. (Personal communication, Department of Planning and Development, 1976.)

[2] Gillette, Wyoming, City of. *Statement of Planning Considerations, February 13, 1976*. Gillette, Wyo.: City of Gillette, 1976.

Finally, energy development at Gillette will result in changes for traditional organized interests and, over the long term, will likely affect the power base that has prevailed in Gillette-Campbell County relations. That is, the control of county affairs by the ranchers will decline to allow representation of Gillette in county government affairs. Like many parts of the West, town and county affairs have been kept distinct; in fact, the population of the town is typically less than that of the remainder of the county. The reverse situation now exists with regard to the city of Gillette and Campbell County, but political power in the county government still is held by the ranchers. It is not clear at what point, in the course of future development, the political balance will shift to meet the population balance. Whenever it does, the changeover will be difficult for long-time residents.[2]

9.4.9 Summary of Social, Economic, and Political Impacts

Of all locations in the western U.S., the Gillette, Wyoming area is expected to be one of the areas most intensively impacted by energy development. The scenario analyzed here indicates that the county population will grow nearly six-fold, with a large part of the growth taking place in or near Gillette. Housing needs and school enrollments will expand similarly. Most new housing units will be mobile homes, reflecting the reluctance of builders, finance firms, and residents to expect anything but short-term growth.

Approximately 3 percent of the land area of Campbell County will be developed as a result of energy activity and population growth. Hunting and other recreational activities are likely to increase, impacting a good deal of the remaining area.

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[1] A further example is the inability of Gillette to expand in preferred directions because of land ownership by parties, including energy developers, who are unwilling to give up their land to urban expansion.

[2] University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974; and Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group. *Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains*, Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 37-73.

Campbell County's economy has already been largely energy-impacted, although primarily in oil and gas production. Through 1985, this concentration in energy should continue, slowly giving way to greater representation of service employment related to population. The energy and service sectors will exceed agriculture in the county in terms of income and employment. A gradual decline in household median income will occur over the 25-year period as a result of the change in industry mix and the growth of relatively lower paying service jobs.

Municipal expenditures for capital facilities and operating budgets are expected to be quite large, particularly in the capital expenditures area where between $30 and $45 million will be needed for each 5-year period. From 1980 to 1985, because of the increasing tax base, the county will have a financial surplus, whereas Gillette will show a deficit. Consequently, concerted effort on the part of both jurisdictions will be needed to meet the demands for public facilities and services.

Social problems resulting from, for example, the large number of mobile homes and the lack of sufficient medical care, will make life especially difficult for newcomers to Gillette. The newcomer/oldtimer disparity is also manifested in political control, which presently remains in the hands of ranchers county-wide. Planning for the future growth of Gillette within the county is thwarted by both these political considerations and the growing power of energy developers in the county.

The major technological choices affecting social, political, and economic impacts in Campbell County are essentially the alternatives between exporting coal or converting it within the local area. The greatest impacts will occur during construction of a conversion facility, which requires 20 to 30 times the laborforce for construction of a mine alone. Thus, construction of mines would not produce so great a fluctuation in the work-force as that which takes place in the scenario during the mid-1980's. Importantly, however, differences in operation of the facilities are not as great as construction, and half the work-force (and attendant population) would not be required if the coal were shipped from the region. However, without the plants, the tax base for Campbell County would significantly diminish.

Other technological choices would produce some change in social impacts. For example, if plant efficiency decreases, due to such factors as dry cooling towers, mining might require 5 percent more labor; if the plants were located at more distant locations, some shifts in population location or commuting might take place. If extensive export mining called for additions to rail service rather than slurry lines, impacts would be difficult to predict and would depend on the extent of new rail access to the region and the degree to which rail lines would be monopolized by coal cars.

Prediction of many of the social and economic impacts depends largely on assumptions in the economic base model and, for example, taxation rates. Improvements in knowledge of the current situation probably would not result in significant improvements in the ability to predict impacts in this area. However, important changes in quality of life and political impacts are more difficult to predict and can only be approached by means of local data, such as surveys of attitudes and aspirations of people within the region, or a greater understanding of the underlying political structure of Gillette and Campbell County.

9.5 ECOLOGICAL IMPACTS

9.5.1 Introduction

The area considered in evaluating the Gillette scenario extends from the Bighorn Mountains eastward to the Black Hills, and northward from the North Platte River to the Montana border. Most of this land is rolling prairie of 4,600 to 5,000 feet in elevation, relieved by stream valleys, and buttes and ridges rising a few hundred feet from the surrounding landscape. The climate is semiarid, with extreme annual variations in temperature which, together with soil moisture and topography, are the major factors affecting the distribution of plant and animal species.[1]

9.5.2 Existing Biological Conditions

There are two major biological communities present in the prairie portion of the study area: sagebrush-grasslands and ponderosa pine woodlands. The sagebrush-grasslands are of several subtypes, a shrubby salt-tolerant greasewood type along streamcourses, and silver sage or big sage dominant in well-drained upland sites. Most of the area is big sage grassland used for grazing cattle. There are a few pure grassland areas that are largely devoid of shrubs.

Antelope and sage grouse, two species which depend heavily on large expanses of sage, are exceptionally abundant in the Gillette area. Wyoming also has almost half the world's population of

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[1] Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains. General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974, p. 4.

TABLE 9-44: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, GILLETTE SCENARIO

Community Type	Characteristic Plants	Characteristic Animals
Sagebrush Grassland	Big sagebrush Silver sagebrush Greasewood Gardner saltbush Alkali sacaton Bluegrass Needle and thread grass Western wheat grass	Antelope Coyote Richardson's ground squirrel Black tailed prairie dog Western harvest mouse Sage grouse Golden eagle
Ponderosa pine Woodlands	Ponderosa pine Rocky Mountain juniper Skunkbush sumac Western snowberry Stoneyhills muhly Green needlegrass Sideoats grama	Mule deer Elk Porcupine Wild turkey Bushytail woodrat Least chipmunk Bobcat
Riparian	Plains cottonwood Sandbar willow Boxelder Wild rose Rubber rabbitbrush Wildrye Wheatgrass Needlegrass	Mule deer Whitetail deer Red fox Meadowvole Mallard Western kingbird Skunk Bobcat Raccoon

pronghorn antelope, and most of these inhabit the study area. Other typical animal species are shown in Table 9-44. Rare or endangered species include the peregrine falcon, bald eagle, black-footed ferret, Northern kit fox; and possibly the other species threatened with extinction also occur in or migrate through the area.[1]

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[1] Northern Great Plains Resources Program, *Effects of Coal Development in the Northern Great Plains: A Review of Major Issues and Consequences at Different Rates of Development*, Denver, Colo.: Northern Great Plains Resources Program, 1975, p. 46.

Ponderosa pine woodlands are found largely in rough topography to the north of Gillette and in a small range of hills to the southeast. The widely spaced trees provide a variety of food plants, cover, and nesting sites for a distinctive bird fauna and a variety of small mammals (Table 9-44).[1]

A small amount of riparian habitat is found in the prairie portion of the scenario area, principally along the Powder, Little Powder, Belle Fourche, and Cheyenne Rivers, and Black Thunder and Lightning Creeks. Composition of this vegetation type ranges from narrow rows of cottonwoods with a shrubby understory to a relatively well-developed floodplain forest. Whitetail deer and a number of other mammals are found principally in these bottom woodlands.

Aquatic habitat is limited in extent in the prairie portion of the scenario area. Flows in the area's major streams--North Platte, Cheyenne, Belle Fourche, and Powder Rivers--vary considerably from both natural runoff and irrigation withdrawals. Warm-water fish species predominate, except below the discharges of several reservoirs in the North Platte. Fish habitat in the Powder, Belle Fourche, and Cheyenne Rivers is limited because extreme summer flow reductions leave only a series of deep holes and pools with little water flowing between them. Species tolerant of these conditions include burbot, carp, white sucker, and fathead minnow. Stock ponds and small irrigation reservoirs usually support largemouth bass and panfish, while larger reservoirs support both warm- and cold-water species. Mountain lakes and streams in the Black Hills and Bighorn Mountains are stocked with trout.

9.5.3 Major Factors Producing Impacts

Between 1975 and 1980, one export coal mine and a natural gas field with processing facilities will be developed. During this period, the population of Campbell County will increase by 85 percent, and the population of Gillette will more than double. A rail spur from the Gillette area to Douglas supports export mines and gathering lines, and a trunk line supports the gas wells. Most of the habitat removed directly by these activities will be sagebrush grassland (Table 9-45).

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[1] Most of the area's birds of prey hunt over both communities; species include Swainson's redtail, and ferruginous hawks, golden eagle, marsh hawk, prairie falcon, kestrel, and great horned owl. Other ubiquitous predators include the coyote, bobcat, and red fox.

TABLE 9-45: LAND CONSUMPTION: GILLETTE SCENARIO (acres)

Community Type	Permanent Loss			Mining
	1975-1980	1980-1990	1990-2000	1977-2000
Grassland	930	400	590	1,870
Shrub grassland	6,430	5,610	2,940	21,530
Pine Woodland	550	230	150	910
Riparian Woodland	130	60	60	300
Total	8,040	6,300	3,740	24,610

Between 1980 and 1990, the second export coal mine and slurry pipeline will be completed, as will the Lurgi gasification facility, a steam electric power plant, and a uranium mill and a 750-kilovolt transmission corridor. As a consequence of the construction and operation of these facilities, the area's population will continue to increase, rising 43 percent from 1980; Gillette will grow by another 39 percent. Water will be withdrawn from the North Platte near Douglas (25 cubic feet per second [cfs]) and the Yellowstone near Miles City (68 cfs) to supply the needs of industrial development.

Between 1990 and 2000, the mine-mouth Synthane high-Btu (British thermal unit) gas and Synthoil liquefaction facilities will be constructed. Additional land will be used for water and product pipeline rights-of-way. Area population will increase by an additional 40 percent by 1995. The population of Gillette will be four times its 1975 level. Cumulative withdrawals of industrial water supplies rise to 82 cfs from the Yellowstone and 52 cfs from the North Platte.

9.5.4 Impacts

A. Impacts to 1980

Initially, alterations in vegetation, the use of land and water resources, and the activities of increased numbers of people will act as the major stresses to ecosystems in the Gillette area. Current forage production estimates on private and federal lands indicate a 4- to 6-acre natural forage requirement to support one cow with calf for a month.[1] Private lands are now overstocked and 3-4 acres are used to feed one cow with calf per month. The loss or preemptive use of 10,740 acres of vegetation in the first 5 years will remove an amount of forage equivalent to that consumed in a year by 120-190 cows with calves or 600-950 sheep.[2]

The expected impact during the first 5 years is relatively minor in this scenario, primarily due to the limited extent of development. The amount of habitat removed by constructing the rail line, opening the first export mine, and developing the gas field with its system of gathering and transmission pipelines will be negligible compared to the total amount of sagebrush-grassland habitat available. Smaller vertebrates will be lost during construction, but many will tend to re-colonize the pipeline rights-of-way after reseeding.[3] Although local impacts in affected areas will eliminate some species,[4] the net impact on areawide populations will be negligible.

The introduction of the rail line, which will carry seven unit trains daily, will interfere with the movements of larger, wide-ranging species such as deer and antelope. Seasonal movements between areas of winter browse and summer feeding and watering will be disrupted. The rail line also bisects two large winter concentration areas. If prevented from movement between winter and summer areas, antelope could decline in abundance, particularly during periods of drought-induced stress. This area is also subject to extensive habitat fragmentation[1] by energy development during subsequent years, which could accentuate this population trend.

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[1] Livestock carrying capacities are expressed as Animal Unit Months (AUM's). An Animal Unit is one cow and her calf or five sheep. An AUM refers to the amount of forage required to support one animal unit for 1 month. AUM's do not refer to wildlife.

[2] Assuming a range of 3.5-6 acres of forage for one Animal Unit Month for grasslands and sagebrush grasslands, and 3.5-4.0 acres for pine and riparian lands.

[3] Species re-colonizing rights-of-way may not be the same as those initially found there, owing to change in vegetation cover.

[4] U.S., Department of the Interior, Bureau of Land Management, et al. *Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming*, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974, p. IV-115.

Livestock production on either side of the railroad right-of-way will also require that it be fenced on both sides. These fences will prevent crossing of the rail line by antelope and will cause occasional, temporary entrapment of deer and antelope within the right-of-way.[2]

B. Impacts to 1990

The construction of the large Lurgi and power generation plants will remove additional areas of sagebrush-grassland habitat, together with small amounts of stream-side vegetation (Table 9-45).

[illegible]n only 9,480 acres are annually irrigated in Campbell County, [illegible],370 acres are irrigated annually along the North Platte in Converse County. The major irrigated crop along the North Platte is hay. Current annual demands for irrigation water from the North Platte are about 60 cfs, and demand exceeds supply. By 1990, the withdrawal of 25 cfs for energy development will locally exacerbate this problem.

Some 7,630 acres of grazing lands will be lost to facilities siting during the second scenario decade. Based on current stocking rates, forage equivalent to that consumed by 90-150 cows with calves or 450-750 sheep in a year will be lost from production. This total includes the temporary losses of livestock forage from clearing pipeline and transmission line rights-of-way. While the proportion of the total extent of habitat lost to facility siting is negligible, the addition of new sites will tend to fragment habitat used by the widest ranging of the area's wildlife: the pronghorn antelope. Fragmentation will increase in the subsequent decade; together with the impact of the railroad, this splitting of the species' range could result in changes in seasonal movements and distribution.[1]

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[1] Habitat fragmentation occurs when the continuous mosaic of habitat types available to area wildlife becomes a discontinuous patchwork because of artificial barriers such as fences, irrigation canals, rail lines, or large barren expanses of mined areas. Wildlife species travel among different habitats daily, and often seasonally, to fulfill food, water, and cover requirements. Barriers which fragment habitat stress wildlife because they limit or prohibit access to these important needs.

[2] There has been some question about the impact of fencing the railroad right-of-way. Though deer can either jump or crawl through/under fences, antelope crawl under them and only rarely attempt to jump.

Increased traffic on the highway parallel to the rail line will constitute a wildlife hazard. The impact of highway kills on areawide populations of smaller wildlife will be negligibly small, but the increased amount of carrion available may, in turn, attract birds of prey and some mammalian predators, which will be vulnerable to road-kill. Because of their low numbers, the threat to bald eagles, which feed on both carrion and live prey, warrants concern, although areawide populations of most other predators are high enough to absorb occasional deaths without decline.

It has been relatively common practice for large energy developers to purchase irrigation water rights as a stop-gap measure to ensure a water supply.[2] If this happened in this hypothetical scenario, conversion of these rights to industrial use could eliminate a portion of the wildlife habitat provided by irrigated crop and pasture land. Although restricted in extent, this habitat type may be important to a number of wildlife species, including ring-necked pheasant and waterfowl as well as a variety of small mammals and birds.

A potential physical hazard is presented by the extra-high voltage power transmission line. Migrating birds may occasionally fly into the wires or suffer electrocution because of corona discharge. However, appropriate design can reduce the problem of electrocuting large birds perching on the towers. The corona discharge from the line could cause wildlife and livestock to avoid the general area.[3]

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[1] Current fencing practices on public lands in the study area are antelope-oriented; that is, bottom fence strands are 14-16 inches above the ground and Bureau of Land Management designed "antelope guards" are provided. Fencing on private lands does not usually incorporate such designs and has likely produced some changes in distribution already.

[2] Industry has already purchased some 12,000 acres of irrigated cropland to obtain the associated water rights. However, as described in Part III, it is not clear that agricultural water rights can be converted for use in energy development.

[3] Research under the sponsorship of the Electric Power Research Institute is intended to reveal the extent to which large power lines can influence wildlife.

Localized adverse impacts may arise from dewatering the surface mines and from contamination of groundwater percolating through these mines after backfilling and revegetation. Mine dewatering may affect the water table as much as 3 miles away.[1] Springs or surface discharges within that distance might become unpalatable to wildlife from contamination by leached salts after flow is resumed.

Increases in the population of the Gillette area over the second decade will induce continuing changes in land-use patterns. The effect of town growth on wildlife populations is irregular and is related to topography and the movements of people, but it probably extends no farther than 20 miles from the outskirts of town into the plains. For most species, a smaller radius (perhaps 10 miles) would include most concentrated day-to-day human activity, the presence of domestic dogs and cats, traffic, noise, and suburban habitat fragmentation that would noticeably reduce the abundance and diversity of terrestrial wildlife. If, however, growth is scattered into small subdivisions along the north-south axis of the coal field, the combined effect on wildlife habitat of both industrial and residential land use would be more extensive than around a single town. This pattern could result if Gillette is unable to finance sewage treatment facilities meeting Environmental Protection Agency standards, thus favoring scattered small developments.

Although the discharge of municipal sewage into area streams is to be controlled during this decade, Gillette will probably continue current discharge practices until about 1985 (Section 9.3). Such discharge could contain harmful amounts of nutrients and perhaps some organic material. Gillette presently discharges its sewage effluent into Donkey Creek, an intermittent stream. Assuming that this practice continues, the added flow could help stabilize the aquatic ecosystem. However, nutrients carried by the wastewater could cause algal blooms in pool habitats, lowering dissolved oxygen levels and causing odor problems as they decay. Further, the Belle Fourche River, about 23 miles downstream, might receive nutrient-laden water from Donkey Creek, although the effects would be significantly diminished.

Larger concentrations of people may bring increases in hunting and poaching, primarily of deer, elk, antelope, and sage grouse. Poaching typically reaches high levels around large construction projects and will have begun to occur in the previous scenario decade. Illegal kills of non-game animals are likely to follow a similar pattern. Birds of prey are usually prime targets, especially those which frequent roadsides such as bald and golden eagles and Swainson's hawks. The peregrine falcon, occasionally seen in the area, and the prairie falcon, a resident, can probably tolerate less of this kind of stress than the more abundant species. Varmint hunting is popular in the area, concentrating mainly on fox, coyote, and bobcat. A major increase in trapping and hunting, due to the increased human population and rising fur prices, could reduce the bobcat and possibly the fox populations. Since coyotes typically do not decline unless concerted efforts are made against them, their numbers could increase slightly as a result of lowered competition with other predators.

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[1] U.S., Department of the Interior, Geological Survey. _Final Environmental Impact Statement: Proposed Plan of Mining and Reclamation, Belle Ayr South Mine, Amax Coal Company, Coal Lease W-0317682, Campbell County, Wyoming_, 3 vols. Reston, Va.: Geological Survey, 1975.

Patterns of recreational land use could shift if private lands are closed to hunting and other recreational uses. This trend is already in evidence around Gillette. Ranchers who close their land will probably keep them closed even after the first population influx has passed. Such actions could reduce illegal game kill on large areas of sage-grassland. This trend would also force outdoor recreationists to almost exclusive use of the area's public lands, particularly the Black Hills and Bighorn National Forests.[1]

Wildlife populations in the Black Hills will probably be affected more severely than those in the Bighorn Mountains due to the proximity of Gillette. While large parts of the Bighorn National Forest are administered as primitive areas and proposed for wilderness classification, the Black Hills National Forest is so well supplied with roads that the Forest Service plans to close some of them to reduce traffic in potential "backcountry" areas.[2] Further, about 20 percent of the area within the Black Hills National Forest boundary is not owned by the Federal government. This land consists of scattered, small, privately held parcels whose subdivision could affect many kinds of wildlife through habitat fragmentation.[1] The net effect of developing recreational forested lands would be to protect, to some extent, animals typical of the well-developed sagebrush grasslands (where energy facilities occur) at the expense of forest ecosystems.

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[1] Lands to the northwest and southeast of Gillette that are under the administration of the Bureau of Land Management (BLM) and Basin National Grasslands or are administered by the Forest Service will be affected to a smaller degree. The BLM lands are important deer and elk habitat; unrestricted use of off-road vehicles in these areas could be particularly harmful to elk, which occupy very restricted ranges.

[2] U.S., Department of Agriculture, Forest Service, Rocky Mountain Region. _Draft Environmental Statement for the Timber Management Plan for the Black Hills National Forest_. Denver, Colo.: Forest Service, 1976.

C. Impacts to 2000

The final scenario decade will see the initiation and completion of two more large construction projects. At present average stocking rates, the forage produced on the 3,740 acres of vegetation destroyed by plant siting would be equivalent to that consumed in a year by 50-90 cows with calves, or 250-450 sheep. Forage losses caused by pipeline construction are temporary.

Recreational and land-use changes along with illegal harvest may adversely affect the two small elk herds in the area (50 in the Rochelle Hills and a larger herd, about 200, along the badlands of the Little Powder River). These herds are too small to sustain continued loss of breeding animals of both sexes. Another factor affecting the vulnerability of elk is the large proportion of their range that lies on public lands. The area's other game species are likely to be protected somewhat by the closure of private lands.

The removal of water from the North Platte River (Section 9.3) will equal 30 percent of historical low flow by 2000. Periodic stress in the aquatic community is likely to occur, at least in years of low flow. Lowered stream flows affect aquatic ecosystems by changing fish distributions and behavior, reducing the productivity of plants and invertebrates, reducing the total bottom area, changing overall water quality, and lowering the rate of food transfer from riffle to pool areas.

Flows in the North Platte are affected by reservoir operation. Reduced flow effects will be greatest in periods of lowest river discharge, principally in winter. At other times, flow is great enough so that water withdrawal in the anticipated amounts will be only a very small portion of the total discharge. Thus, spring or fall fish spawning is not likely to be influenced. In the drier months, increasing stress to game might conceivably bring about species shifts favoring non-game fishes.[2]

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[1] Particularly vulnerable are whitetail deer, which winter at lower elevations, largely outside the forest boundary.

[2] These non-game fishes have more flexible habitat requirements and include carp, white sucker, river carpsucker, buffaloes, and bullheads. Non-game species which may be adversely affected include the stonecat and shorthead redhorse.

Dewatering will also reduce the extent of habitat available to wintering waterfowl. Large numbers of mallards, green-winged teal, golden-eye, and mergansers, together with some geese, winter on the North Platte below Glenrock.

Both airborne and waterborne industrial wastes can introduce hazardous substances into the environment. Under most conditions, combined plant emissions should not add significantly to ground-level pollutant concentrations. Consequently, acute air pollution damage to vegetation or animals does not seem likely. Since the total land area exposed to airborne pollutants does reflect the number of emission sources, low-level exposure to sulfur dioxide will cover a broad area downwind of the line of developments. Peak ground-level concentrations will be highest--323 milligrams per cubic meter (0.13 parts per million) 3-hour average--downwind of the plant. These concentrations are below those generally thought to cause acute vegetation damage (see Section 12.5).

Some evidence suggests that fine particulate matter originating in the Great Plains is reduced over the Black Hills by the scavenging effects of precipitation and by the ability of vegetation to act as a filter.[1] The latter mechanism may account for as much as a two-fold reduction in particulate concentration. Thus, much of the sulfates and sulfites emitted as fine particulates or forming subsequently in the atmosphere may be deposited in the Black Hills. This phenomenon would carry with it the possibility of slight soil acidification, but total emissions are far below levels which have been associated with locally acid rainfall or chronic damage to plants. The tendency toward soil acidification will probably also be small. Other influences in the same time frame may have a greater affect on overall vegetation productivity and influence the ecosystems at large. Grazing and drought will remain the principal factors limiting the productivity of prairie vegetation, while the intent of the Forest Service to manage the Black Hills National Forest intensively as a system of small, even-aged stands[2] override the influence of long-distance transport of air pollutants from Gillette as an overall habitat influence.

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[1] Davis, B.L., et al. The Black Hills as a "Green Area" Sink for Atmospheric Pollutants, First Annual Report, prepared for the USDA Rocky Mountain Forest and Range Experiment Station, Report 75-8. Rapid City, S.D.: South Dakota School of Mines and Technology, Institute of Atmospheric Sciences, 1975.

[2] U.S., Department of Agriculture, Forest Service, Rocky Mountain Region. Draft Environmental Statement for the Timber Management Plan for the Black Hills National Forest. Denver, Colo.: Forest Service, 1976.

TABLE 9-46: POTENTIAL LIVESTOCK PRODUCTION FOREGONE: GILLETTE SCENARIO

		Animal Equivalent	
Acres Lost		(Cows with Calf)	Sheep
1975-1980	8,040	90-150	130-200
1980-1990[a]	6,300	70-120	100-170
1990-2000	3,740	40-70	60-100
Post-2000[b]	3,980	40-70	60-100
Cumulative Total	22,060	240-410	350-570
1974 Inventory,[c] Campbell County		91,893	126,890[d]
Loss as Percent of 1974 Inventory		0.3-0.4	0.3-0.5

[a] Includes transmission line rights-of-way.

[b] Acreage represents lands not fully reclaimed in any given year with all mines having been operating longer than 5 years.

[c] U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture: Preliminary Report, Campbell County, Wyoming. Washington, D.C.: Government Printing Office, 1976.

[d] Includes lambs.

D. Impacts After 2000

The cumulative impact of facilities siting, including mining, on potential livestock production has been summarized in Table 9-46.[1] The distribution of livestock among sheep and cattle is according to the ratio of inventories recorded in the

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[1] Several simplifying assumptions have been made in preparing this table, which may bias it toward conservatism. Among these are: including transmission and pipelines rights-of-way as losses, even though grazing values will be at least partially restored; assuming that no grazing takes place on strip mine spoils until 5 years after mining; and assuming that all lands to be disturbed would otherwise be grazed.

1974 Census of Agriculture. However, even with conservative assumptions, it is apparent that the cumulative forage production lost is equivalent to the yearly requirements of less than 1 percent of the 1974 livestock inventory.

Mined-out areas can be re-contoured and a plant cover of some kind restored. However, because of the difficulty of replanting shrubs in their original density, only the 1,870 acres of pure grassland of the 24,670 acres affected by mining will be returned to a state structurally similar to its original condition. In some instances, obtaining adequate quantities of plant materials may limit reclamation efforts.[1] Assuming that reclamation focuses only on forage production, 22,795 shrubby or wooded acres will be effectively lost and replaced by a grassforb mixture. This total will consist of 17,880 acres of sagebrush grassland, 3,700 acres of silver sage, 915 acres of pine woodland, 578 acres of greasewood, and 300 acres of riparian woodland.

Experimental work in the Gillette area has shown that a cover of range grasses can be established on regraded mine spoils. Opinions differ on the length of time required to establish self-sustaining vegetation, but this technology assessment assumes that 5 years will be sufficient, after which there will be no further manipulation of the revegetated area. However, since spoil material lacks the structure of soils developed over longer periods, moisture in the revegetated mine spoils will probably not be as good (nor natural nutrient cycles as effective) as those in native soils. Further, since soil moisture availability and fertility are usually the major factors limiting plant growth on spoils from this part of the Fort Union Formation, revegetated areas may have less dense plant cover, lower productivity, and exhibit less stability in the face of such stresses as grazing or the region's periodic droughts than adjacent undisturbed vegetation. In consequence, the net effect of mining will probably be to convert roughly 23,000 acres of shrubland to a less productive, probably less stable early-successional type of grassland.[2]

The ecological impact of reclamation changes can be qualitatively described, based on successional patterns observed on abandoned farmland in the area.[1] Table 9-47 is a classification of area animals according to their preference for different vegetation types. (Figure 9-9 shows the expected changes in area animal populations on lands reclaimed with varying success.) This diagram shows that, during the 1980-2000 time period, most of the mined lands will be in an early stage of succession (modified by early introduction of perennial grasses). For example, ground squirrels, pocket gophers, and kangaroo rats will be abundant if spoil conditions permit burrowing, although on some mines, spoil textures may limit their occurrence. However, total numbers or biomass of these small vertebrates may be less than the original population, especially if grazing is permitted or plant cover is low. In contrast, those Group 1 species that depend on mature sage stands will be found in very small numbers. The resulting local change in prey species composition will probably not cause a change in the relative abundance of different predators. Potential exceptions are the golden and wintering bald eagles and the larger buzzard hawks, which prey heavily and sometimes almost exclusively on rabbits. The overall impact of hunting, trapping, and illegal shooting will probably have a more important effect on predator numbers than mining.

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[1] Hassel, M.J. "The Surface Environment and Mining (SEAM) Program," *Western Wildlands*, Vol. 1 (No. 4, 1974), p. 35.

[2] A more detailed discussion of surface mine reclamation is presented in Chapter 12.

9.5.5 Summary of Ecological Impacts

The sources and expected period of major ecological impacts are shown in Table 9-48. Major impacts of the Gillette scenario are ranked according to the total area and number of species which they affect in Table 9-49.

Class A impacts are considered most severe because they affect the largest number of species over an extensive area. In this scenario, habitat fragmentation takes place in a large area important to antelope. Poaching and illegal shooting affect both game and non-game species and are often widespread.

Another direct impact of the scenario is the low-flow reduction in the North Platte River from cumulative water withdrawals. Although uncertain due to lack of knowledge about the river channel in the scenario area, some detectable changes in the productivity of the ecosystem may result, at least during years of below-average flow.

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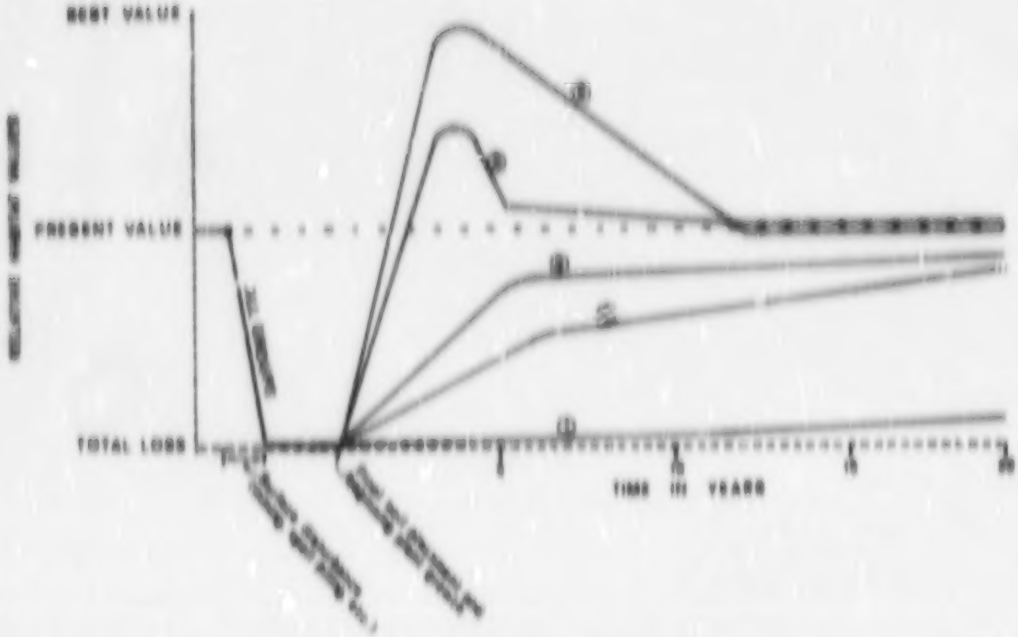
[1] U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974; and Lang, R.L. "Vegetation Changes Between 1943 and 1965 on the Shortgrass Plains of Wyoming." Journal of Range Management, Vol. 26 (November 1973), pp. 407-409.

TABLE 9-47: HABITAT GROUPS OF SELECTED ANIMALS REPRESENTATIVE OF THE STUDY AREA

Group I Animals heavily dependent on sagebrush for food or cover or nesting sites or combination thereof and/or other upland shrubs such as greasewood, saltbush, and rabbitbrush, especially for winter feed	Pronghorn Antelope Mule Deer White-tailed Deer Sagebrush Vole Deer Mouse Least Chipmunk White-tailed Prairie Dog White-tailed Jackrabbit
Group II Animals feeding heavily on seeds and/or foliage or roots of woody species of forb or annual grasses and/or nesting on ground in open grasslands	Thirteen-lined Ground Squirrel Richardson's Ground Squirrel Northern Pocket Gopher Wyoming Pocket Gopher Ord's Kangaroo Rat Western Harvest Mouse
Group III Animals nesting on the ground in open grasslands and/or feeding primarily on perennial grass seeds or foliage	Black-tailed Prairie Dog Prairie Vole Chestnut Collared Longspur McCown's Longspur
Group IV Animals that depend primarily on the riparian (stream-side) plant associations and/or marshy or moist meadow areas around lakes or ponds to directly or indirectly provide food or cover or nesting or breeding sites	Raccoon Mink Striped Skunk Beaver Muskrat Long-tailed Vole Black-billed Magpie Red-shafted Flicker
Group V Animals requiring the open pine timber, juniper breaks or rough, rocky topography for cover or food or nesting sites	Elk Bushytail Wood Rat Porcupine Pygmy Nuthatch Cassins Kingbird White-winged Junco Pinon Jay

Source: U.S., Department of the Interior, Bureau of Land Management, et al. *Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming*, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.



Curve Number	LEGEND Animal Group (list of animals in each group is found in Table 9-47)
1	Group 1
2	Group 2 (projected rehabilitation unsuccessful)
3	Group 3 (projected rehabilitation successful)
4	Group 4 (projected rehabilitation unsuccessful)
5	Group 5 (projected rehabilitation successful)

Source: U.S., Department of the Interior, Bureau of Land Management, *et al.* *Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming*. 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

FIGURE 9-9: EXPECTED HABITAT VALUE TRENDS FOR PARTICULAR ANIMAL GROUPS AFTER DISTURBANCE WITH ATTEMPTED REHABILITATION TO PERENNIAL GRASSLANDS

TABLE 9-48: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

Impact Category	1975-1980	1980-1990	1990-2000
Class A	Habitat fragmentation	Habitat fragmentation	Habitat fragmentation
		Poaching and illegal shooting	Poaching and illegal shooting
		Stream flow reductions	Stream flow reductions
	Increased recreational use of public lands	Increased recreational use of public lands	Increased recreational use of public lands
Class B	Growth of Gillette	Growth of Gillette	Growth of Gillette
Class C	Grazing losses (facilities siting)	Grazing losses (facilities siting)	Grazing losses (facilities siting)
Uncertain			Sulfate fallout in Black Hills
		Irrigated agricultural losses	Irrigated agricultural losses

TABLE 9-49: FORECAST OF STATUS OF SELECTED SPECIES[14]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

TABLE 9-49: (Continued)

	[illegible]	[illegible]	[illegible]
[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]
[illegible] [illegible] [illegible]	Little change.	[illegible]	[illegible]
[illegible][b]	Little change.	[illegible]	[illegible]
[illegible] [illegible]	Little change.	[illegible]	[illegible]
[illegible] [illegible]	Little change.	[illegible]	[illegible]
[illegible]	Little change.	[illegible]	[illegible]
[illegible]	Little change.	[illegible]	[illegible]

[a] [illegible]

[b] [illegible]

[c] [illegible]

Finally, the greatest potential impact arises from the indirect land use pressures of a large increase in population. Especially significant is game poaching during construction peaks, which may decimate the area's small elk herds.

Suburban habitat fragmentation, concentrated human activity, and similar localized impacts associated with growth of an urban center such as Gillette are ranked as Class B impacts. Though they may affect several species, the geographic area in which the impacts are realized is relatively small.

Because the geographic area affected by facilities siting is small compared to the total amount of similar available habitat, grazing losses are given the most minor of rankings: Class C.

The cumulative impact of facility siting on habitat quantity and quality will principally reflect the success of reclamation and the degree to which habitat is fragmented and the movements of wide-ranging species are disrupted by the new rail line and its parallel high-traffic highway. Antelope will probably be most sensitive to this impact because of the large range they normally occupy.

9.6 OVERALL SUMMARY OF IMPACTS AT GILLETTE

The intended energy benefit from the hypothetical developments in the Gillette area will be the production and shipment of 50 million tons of coal per year, 100,000 barrels of synthetic oil, 750 million standard cubic feet per day of synthetic and natural gas, and 3,000 megawatts of electricity. In addition, 1,000 metric tons per year of yellowcake will be produced for enrichment for nuclear reactors. Locally, the benefits include increased income to the city and county, increased retail and wholesale trade, and secondary economic development. Campbell County will also receive increased tax revenues as will the state of Wyoming.

Social, economic, and political changes in Campbell County will stem primarily from a six-fold growth in population. Housing demands will be largely met by mobile homes. Nearly 10 percent of Campbell County will undergo changes in land use adding significantly to the assessed valuation. However, the tax base for Gillette will not increase enough to meet new demands placed on public services, and the political strength within the county may shift from ranchers and businessmen to energy developers.

Technological variables affecting these impacts are primarily alternatives between exporting coal or converting it within Campbell County. Construction of conversion facilities requires 20 to 30 times the labor of a mine alone and would not produce great fluctuations in the workforce. However, if the coal were shipped from the region, the tax base for Campbell County would significantly diminish. If export mining resulted in increased rail service rather than slurry lines, impacts would depend on the extent of new rail access to the region and the degree to which rail lines would be monopolized by coal cars.

Both the Synthoil plant and natural gas production facilities emit hydrocarbons (HC) in amounts that will result in ambient air concentrations in excess of both Wyoming and federal standards. In addition, current levels of HC in the city of Gillette are estimated to be in excess of standards, and any addition from the plants and additional urban growth will exacerbate this problem. If the Black Hills National Forest to the east is reclassified as a Class I area, significant deterioration increments for sulfur dioxide will be exceeded. In addition, the plumes of the plants will be visible from many locations in the area, and average long-range visibility will be reduced by up to 8 percent when all the facilities are operating. Under adverse meteorological conditions, visibility will be reduced an even greater extent.

Several potential air controls could ameliorate the extent of the air impacts, although the HC problem cannot be solved short of enclosing the entire plant or making major improvements in valve and flange design. Either a reduction in plant size, improved scrubbers, or coal washing to remove inorganic sulfur would reduce sulfur emissions to minimize potential conflicts with significant deterioration standards. Increasing precipitator efficiency to 99.5 percent would result in less reduction in visibility and reduce emissions of most trace elements by 50 percent.

Water consumption of about 102,500 acre-feet per year for the energy facilities will significantly affect the streams used as water sources, especially the North Platte River where the low flow will be reduced by about 30 percent. This reduction in flow would also increase in-stream salinity and affect downstream agricultural users as well as the quality of water for aquatic life. Groundwater quality may also be affected by leaching chemicals from settling ponds and by the erosion of storage ponds. Surface-water quality in the immediate vicinity of Gillette is also threatened by inadequate sewage treatment facilities.

Technological changes could significantly affect the consumptive use of water. One small power plant in the Gillette region is currently using dry cooling, and the potential exists for using dry cooling towers or wet-dry cooling for the hypothetical conversion facilities in this scenario. This would significantly affect the potential conflicts that might arise from using the waters of the North Platte or in transporting water from the Yellowstone River in Montana to Wyoming.

Significant ecological impacts include converting approximately 43,000 acres of vegetation to plants and mines. Much of this land will be returned to grassland following reclamation. However, this change, together with habitat fragmentation, will likely decrease productivity of selected species. Combined with habitat attrition and poaching from the increased population, some species of game will be adversely affected unless positive steps are initiated in protection and game management. Consumptive use of water for plant cooling and slurry transport will reduce the extent of riparian habitat and the quality of the aquatic ecosystem, and the new rail line will limit movement of antelope, reducing population size. The principal technological variables affecting ecological impacts include population size and water consumption addressed above, and alternative methods for transporting energy resources.

CHAPTER 10

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE COLSTRIP AREA

10.1 INTRODUCTION

The Colstrip area of Rosebud County in southeastern Montana is shown in Figure 10-1. The hypothetical developments proposed for this scenario consist of surface coal mining, an electrical power generating plant, Lurgi and Synthane high-Btu (British thermal units) gasification plants, and Synthoil coal liquefaction (Figure 10-2). Extra-high voltage transmission lines transport electricity from the power plant to demand centers in the midwestern U.S.[1] These facilities are to be constructed between 1977 and 2000. Coal characteristics, technological alternatives, and the scenario's development schedule are summarized in Table 10-1.

Rosebud County's 1975 population was about 8,500, with agriculture the major source of earned income (33 percent in 1972). Other major sectors of economic activity are government, wholesale and retail trade, and construction. Construction activity has increased substantially as a result of recent energy development in the area. Per-capita income in Rosebud County has been slightly lower than the Montana average, averaging out the prosperous ranching activity and the relative poverty of the Northern Cheyenne Indians, who comprised 28 percent of the population in 1970.

The area around Colstrip is generally a semiarid plateau, dissected by several tributaries of the Yellowstone River. The topography ranges from gently rolling basins to rugged uplands and eroded buttes. Rangeland accounts for 77 percent of the

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[1] While this hypothetical development may parallel developments proposed by Northern Natural Gas, Western Energy, Westmoreland Resources, AMAX Coal, Montana Power, and others, the development identified here is completely hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

FIGURE 10-1: THE COLSTRIP SCENARIO AREA

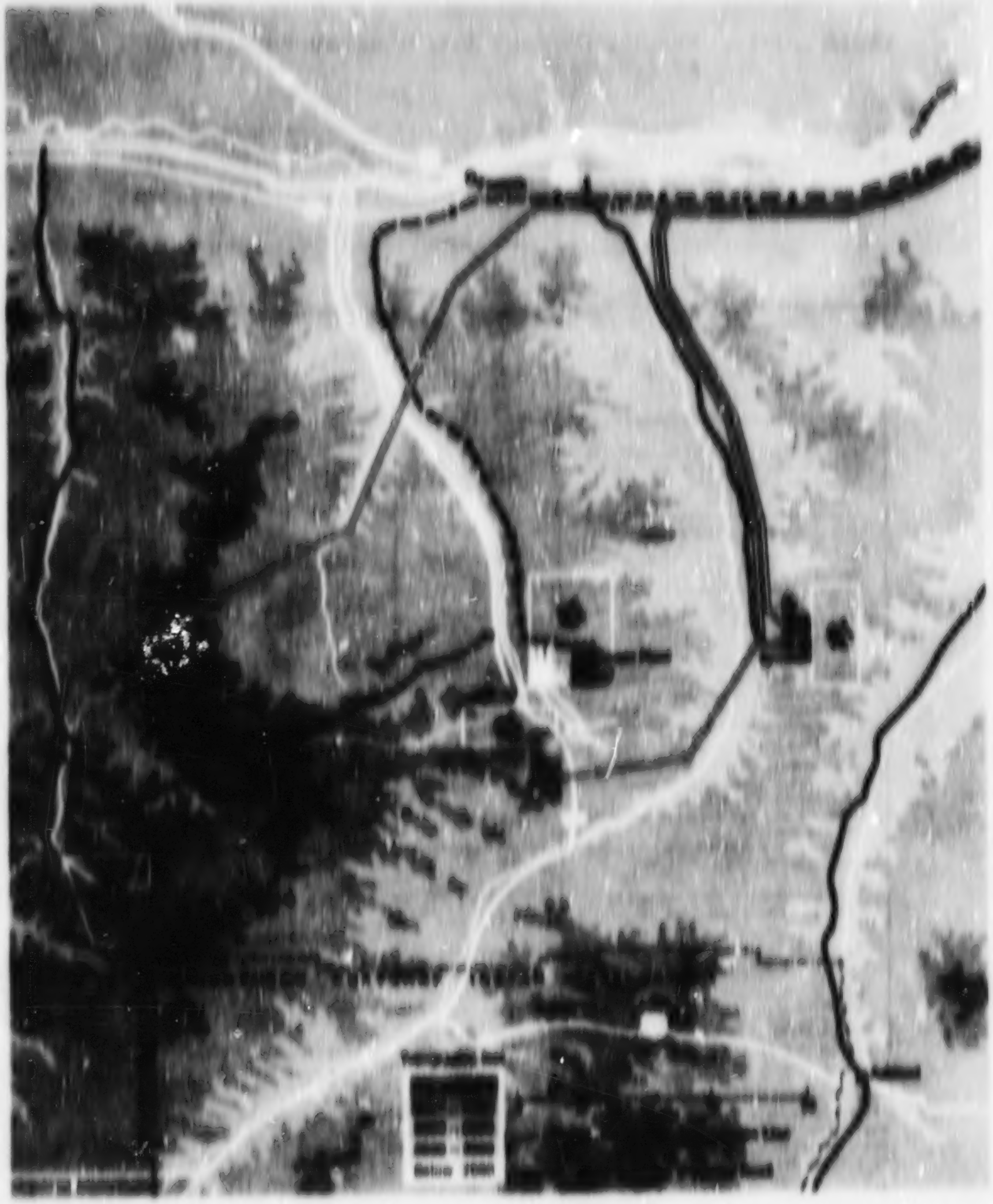

FIGURE 10-2: THE LOCATION OF ENERGY DEVELOPMENT FACILITIES AT COLSTRIP

TABLE 10-1: RESOURCES AND HYPOTHESIZED FACILITIES AT COLSTRIP

Resource	Characteristics		
Coal[a] (billions of tons) Resources [illegible] Strippable Reserves [illegible]	Coal[b] Heat Content [illegible] Btu's/lb Moisture [illegible] % Volatile Matter [illegible] % Fixed Carbon [illegible] % Ash [illegible] % Sulfur [illegible] %		
Technologies	**Facility Size**	**Completion Date**	**Facility Serviced**
Extraction Coal Four surface area mines of varying capacity using draglines	[illegible] MMtpy [illegible] MMtpy [illegible] MMtpy [illegible] MMtpy	[illegible] [illegible] [illegible] [illegible]	Power Plant Lurgi Synthane Synthoil
Conversion One 3,000-MWe power plant consisting of four 750-MWe turbine generators; 35% plant efficiency; 80% efficient limestone scrubbers; 99% efficient electrostatic precipitator; and wet forced-draft cooling towers.	750 MWe 750 MWe 1,500 MWe	[illegible] [illegible] [illegible]	
One Lurgi Coal gasification plant operating at [illegible]% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers.	250 MMscfd	[illegible]	
One Synthane Coal Gasification Plant operating at [illegible]% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers.	250 MMscfd	[illegible]	
One Synthoil Coal Liquefaction Plant operating at [illegible]% thermal efficiency; Claus plant H_2S removal; and wet forced-draft cooling towers.	100,000 bbl/day	2000	
Transportation Coal Transportation from the mines to facilities provided by trucks			
Gas One 30-inch pipeline	250 MMscfd	[illegible]	Lurgi Plant
Oil One 16-inch pipeline	100,000 bbl/day	2000	Synthoil Plant
Electricity Four 500-kV lines	500 kV 500 kV 500 kV (2)	[illegible] [illegible] [illegible]	Power Plant Power Plant Power Plant

bbl/day = barrels per day
Btu's/lb = British thermal units per pound
H_2S = hydrogen sulfide
kV = kilovolts

MMscfd = million standard cubic feet per day
MMtpy = million metric tons per year
MWe = megawatts-electric

[a] Montana Energy Advisory Council. *Coal Development Information Packet*. Helena, Mont.: State of Montana, 1976.

[b] [illegible], and [illegible]. *Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience*. [illegible]. Dayton, Ohio: Monsanto Research Corporation, 1975.

TABLE 10-2: SELECTED CHARACTERISTICS OF THE COLSTRIP AREA

Environment	
Elevation	3,000-4,000 feet
Precipitation	12-16 inches annually
Air Stability	Air stagnation most frequent during fall and winter
Vegetation	Ponderosa pines at higher elevations; rolling grasslands at lower elevations
Social and Economic[a]	
Landownership	
Federal	4.7 %
State	5.1 %
Private	90.2 %
Population Density	1.69 per square mile
Unemployment[b]	4.6 %
Income[c]	$3,751 per capita annual

[a] Rosebud County.

[b] 1970 Data.

[c] 1972 Data.

county. Although most land in Rosebud County is privately owned, the federal government owns much of the mineral rights.

Both groundwater and surface water are available in the area, the latter primarily from the Yellowstone and Tongue rivers and Rosebud Creek. Air quality in the area is good, the major present pollutant being blowing dust. Selected characteristics of the area are summarized in Table 10-2.

10.2 AIR IMPACTS

10.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Colstrip area is currently affected by several sources of air emissions, the largest of which are the Colstrip 1 and 2 generating facilities and the Ashland Timber

Company. Coal strip mines in the area may also cause some localized increases in pollutant concentrations. Measurements of concentrations of criteria pollutants[1] taken in the Colstrip area do not violate any federal or Montana standards. Based on these measurements, annual average background levels for three pollutants have been estimated (in micrograms per cubic meter) as: sulfur dioxide (SO_2), 6; particulates, 15; and nitrogen dioxide (NO_2), 10.[2]

B. Meteorological Conditions

The worst dispersion conditions for the Colstrip area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), unchanging wind direction, and relatively low mixing depths.[3] These conditions are likely to increase concentrations of pollutants from both ground-level and elevated sources.[4] Since worst-case conditions differ at each site, predicted annual average pollutant levels vary among sites even if pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion more than 27 percent of the time. Hence, plume impaction[5] and limited plume mixing caused by temperature inversions at stack height can be expected to occur regularly.[1] Favorable dispersion conditions associated with moderate winds and large mixing depths are expected to occur about 14 percent of the time.

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[1] Criteria pollutants are those for which ambient air quality standards are in force; carbon monoxide, non-methane hydrocarbons, nitrogen dioxides, oxidants, particulates, and sulfur dioxide. The term "hydrocarbons" is generally used to refer to non-methane hydrocarbons. The HC standard serves as a guideline for achieving oxidant standards.

[2] These estimates are based on the Radian Corporation's best professional judgement. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are now assumed to be relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

[3] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[4] Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emitters.

[5] Plume impaction occurs when stack plumes run into elevated terrain because of limited atmospheric mixing and stable air conditions.

The pollution dispersion potential for the Colstrip area varies considerably with the season and time of day. Fall and winter mornings are most frequently associated with poor dispersion due largely to low wind speeds, low mixing depths, and the prevalence of high-pressure systems during these seasons. The highest potential for dispersion occurs during the spring when low-level winds are strongest.

10.2.2 Emission Sources

The primary emission sources in the Colstrip scenario are a power plant, three conversion facilities (Lurgi, Synthane, and Synthoil), supporting surface mines, and those associated with population increases. The largest of these sources, the power plant, has four 750-megawatts-electric boilers, each with its own stack.[2] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of particulates and a scrubber which removes 80 percent of the SO_2 and 40 percent of the NO_x. The plants have two 75,000-barrel storage tanks, with standard floating roof construction, each of which will emit about 0.7 pound of hydrocarbons (HC) per hour.

Most mine-related pollution will originate from diesel engine combustion products, primarily nitrogen oxides, HC, and particulates. Although water spray will be used to suppress dust in this scenario, some additional particulates will occur from blasting, coal piles, and blowing dust.[3] Pollution from energy-related population increases will be mainly due to additional automobile traffic. Concentrations have been estimated from available data on average emission per person in several western cities.[4]

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[1] See National Climatic Center. *Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities.* Ashville, N.C.: National Climatic Center, 1975.

[2] Each stack is 500 feet high.

[3] The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency is investigating this question and will be used to inform further impact analysis.

[4] Refer to the introduction to Part II for identification of these cities and references to methods used to model urban meteorological conditions. This scenario models urban concentrations only for Colstrip, Montana.

TABLE 10-3: EMISSIONS FROM FACILITIES
(pounds per hour)

Facilities[a]	Particulates	SO_2	NO_x	HC	CO
3,000-MWe Power Plant					
Mine	14	9.2	136	70	18
Plant	2,793	14,000	18,900	524	1,752
Lurgi					
Mine	7.7	5	69	8	42
Plant	450	686	2,135	47	310
Synthane					
Mine	6.9	4.6	63	7.8	38
Plant	213	478	1,200	24	160
Synthoil					
Mine	10	6.7	92	11	70
Plant	316	946	1,350	4,616	161

CO = carbon monoxide
HC = hydrocarbons
MWe = megawatts-electric
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

[a] A detailed description of each plant is contained in the Energy Resource Development Systems description to be published as separate report in 1977. Stack parameters, heights and pollutant emission rates are described in detail.

The power plant and the three coal conversion facilities are cooled by wet forced-draft cooling towers. Each cell circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,200 pounds per year for each cell.[1]

10.2.3 Impacts

Table 10-3 lists emissions of five criteria pollutants for each of the four facilities. In all four cases, most emissions come from the plants rather than the mines. The largest single contributor to total emissions is the power plant for all pollutants except HC, in which case the Synthoil plant has the highest emissions. For all five pollutants, the Synthane plant has the smallest total emissions.

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[1] The power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

A. Impacts to 1980

1. Pollution from Facilities

Construction of the hypothetical power plant will begin during this period, but the plant will not become operational until after 1980. Few air quality impacts will be associated with the construction phase of the plant, although construction activity will cause increases in wind-blown dust which may cause periodic violations of 24-hour ambient particulate standards.

2. Pollution from the Town

The population of Colstrip should increase from the 1975 level of 3,000 to 4,080 by 1980.[1] This increase will contribute to increases in pollution concentrations due solely to urban sources. Table 10-4 lists predicted concentrations of the five criteria pollutants measured in the center of town and at a point 3 miles from the center of town. This information shows that the only ambient standard violated in Colstrip due to urban sources is that for HC.[2]

B. Impacts to 1990

1. Pollution from Facilities

The power plant will become operational in 1985, and a Lurgi gasification plant will become operational in 1989. Tables 10-5 and 10-6 give typical and peak pollutant concentrations after these plants come on-line. Peak concentrations from the plants will not violate any federal or Montana ambient air standards.[3]

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[1] Refer to Section 10.4.3.

[2] Hydrocarbon standards are violated regularly in most urban areas.

[3] Interactions of the pollutants from the plants are minimal because they have been (hypothetically) sited 6 miles apart. If the wind blows directly from one plant to the other, plumes will interact. However, the resulting concentrations would be less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentration). The predicted peak level increases from plant interactions are from 0.6-0.8 micrograms per cubic meter ($\mu g/m^3$) for particulates; 2.7-2.8 $\mu g/m^3$ for sulfur dioxide; and 3.6-5.1 $\mu g/m^3$ for nitrogen dioxide. Had the plants been sited closer together, the probability of interactions would increase. Sensitivity analysis of this siting consideration will be done during the remainder of the study.

TABLE 10-4: POLLUTION CONCENTRATIONS AT COLSTRIP
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]							Standards[b]		
	Background	Mid-Town Point			Rural Point			Primary	Secondary	Montana
		1980	1990	2000	1980	1990	2000			
Particulates										
Annual	25	8	10	13	1	1	2	75	60	75
24-hour		27	36	46	27	36	46	260	150	200
SO_2										
Annual	6	4.5	5	7	0	0	1	80		60
24-hour		25	27	28	25	27	28	365		260
3-hour		27	30	42	27	30	42		1,300	750
NO_2[c]										
Annual	10	13	16	21	1	2	3	100	100	
HC[d]										
3-hour		210	270	351	223	270	361	160	160	
CO										
8-hour		952	1,056	1,320	907	1,056	1,320	10,000	10,000	
1-hour		1,478	1,738	2,163		1,738	2,163	40,000	40,000	

CO = carbon monoxide NO_2 = nitrogen dioxide
HC = hydrocarbons SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations for urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary and Secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 50 percent of nitrogen oxide from urban sources is converted to NO_2. Refer to the introduction to Part II.

[d] The 3-hour HC standards is measured at 6-9 a.m.

TABLE 10-5: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration[a]					Standards[b]				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	Colstrip	Primary	Secondary	Montana	Class I	Class II
Particulates										
Annual	20		0.5	0.5	1.3	75	60	75	5	10
24-Hour		5.6	27	22	29	260	150	200	10	30
SO_2										
Annual	6		2.7	2.7	0.5	80		60	2	15
24-Hour		26	87	91	57	365		260	5	100
3-Hour		31	487	487	261		1,300	755	25	700
NO_2[c]										
Annual	10		3.6	3.6	2.2	100	100			
HC[d]										
3-Hour		4.7	40	60	45	160	160			

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered the best estimates of short-term background levels. Concentrations near Colstrip are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-significant deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 11.

[c] It is assumed that all nitrogen oxide from plant exhaust is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 10-6: POLLUTION CONCENTRATIONS FROM LURGI PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration[a]					Standards[b]				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	Colstrip	Primary	Secondary	Montana	Class I	Class II
Particulate										
Annual	35		0.3	0.6	0.1	75	60	75	5	10
24-hour		1.9	3.6	5.1	2.5	260	150	200	10	30
SO_2										
Annual	6		0.6	0.8	0.2	80		60	2	15
24-hour		2	6	8.3	3.6	365		260	5	100
3-hour		0.4	60	60	8.7		1,300	750	25	700
NO_2[c]										
Annual	20		0.6	1.5	3.3	100	100			
HC[d]										
3-hour		3.2	9	25	0.7	160	160			

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical Lurgi plant/mine combination. Annual average background levels are considered the best estimates of short-term background levels. Concentrations near Colstrip are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

Tables 10-5 and 10-6 also list Non-Significant Deterioration (NSD) standards, which are the allowable increments of pollutants which can be added to areas of relatively clean air (i.e., areas with air quality better than those allowed by ambient air standards).[1] "Class I" is intended to designate the cleanest areas, such as national parks and forests.[2] Peak concentrations attributable to the power and Lurgi plants, including contributions from their associated mines, do not exceed Class II allowable increments. However, the Lurgi plant exceeds Class I increments for the 24-hour and 3-hour SO_2 averaging times. Peak concentrations from the power plant will exceed all Class I increments except that for annual particulates, with typical concentrations violating the 24-hour and 3-hour SO_2 increments.

Since the plants exceed Class I increments, they would have to be located a sufficient distance from any Class I areas so that emissions will be diluted by atmospheric mixing to acceptable concentrations prior to reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations require a minimum buffer zone of 75 miles for the power plant and 7.8 miles for the Lurgi plant between these plants and any Class I area boundary.[3] There are no Class I areas within the Lurgi plant's buffer zone, but the Custer National Forest southwest of Colstrip is a potential Class I area which, if redesignated, could result in a violation from the power plant.[4]

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[1] Non-Significant Deterioration standards apply only to particulates and sulfur dioxide.

[2] The Environmental Protection Agency initially designated all Non-Significant Deterioration areas Class II and established a petition and public hearing process for redesignating areas Class I or Class III. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

[3] Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area "wind roses", which show wind direction and strength patterns for various areas and seasons. Hence, the direction of Non-Significant Deterioration areas from energy facilities will be critical to the size of the buffer zone required.

[4] Currently, all Non-Significant Deterioration areas are Class II.

2. Pollution from the Town

Colstrip's predicted population increase to 5,250 will cause some increases in urban pollutants (Table 10-4). As in the 1980 case, the HC standard will be the only one violated. All other pollutant concentrations remain well within federal and state standards.

C. Impacts to 2000

1. Pollution From Facilities

Two new facilities, a Synthoil liquefaction plant and a Synthane gasification plant, will become operational between 1990 and 2000. Tables 10-7 and 10-8 list typical concentrations from the plants, peak concentrations from the plants, and peak concentrations from the plant and associated mine combinations. These data show that no ambient standards will be violated by the Synthane plant. The Synthoil plant will exceed only the 3-hour HC standard but will do so by a factor of more than 100 to 1.[1]

Neither of the new facilities exceeds any Class II PSD increments. However, both plants will violate the Class I increments for 24-hour and 3-hour SO_2. In addition, the Synthoil plant will exceed the Class I increment for annual SO_2, and typical concentrations from this plant approach the 3-hour SO_2 increment. These potential violations would require buffer zones of 13.4 miles for the Synthoil plant and 7.1 miles for the Synthane plant.

2. Pollution from the Town

Colstrip's population will increase to 7,910 by the year 2000, and some increase in pollution concentrations will be associated with this growth (Table 10-4). Although the ambient standard for 3-hour HC is exceeded, no other ambient standards are closely approached.

10.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may effect levels of these pollutants during the next 25 years. These categories of potential impacts are sulfates, oxidants,

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[1] Interactions between the new Synthoil and Synthane plants and the Lurgi and electrical generation plants will increase annual peak concentrations. However, these increases will be small and cause no standard violations.

TABLE 10-7: POLLUTION CONCENTRATIONS FROM SYNTHOIL PLANT
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations^a				Standards^b				
			Peak		Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Colstrip	Primary	Secondary	Montana	Class I	Class II
Particulate									
Annual	25		0.6		75	60	75	5	10
24-hour		3	9	0.6	260	150	200	10	30
SO_2									
Annual	6		2.6	0.1	80		60	2	15
24-hour		7.2	27	1.9	365		260	5	100
3-hour		25	92	7		1,300	655	25	700
NO_2^c									
Annual	10		6	0.5	100	100			
HC^d									
3-hour		420	27,200	5.1	160	160			

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical synthoil plant. Annual average background levels are considered the best estimates of short-term background levels. Concentrations near Colstrip are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once a year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant emission is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 10-8: POLLUTION CONCENTRATIONS FROM SYNTHANE PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]					Standards[b]				
			Peak			Ambient			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	Gillette	Primary	Secondary	Wyoming	Class I	Class II
Particulates										
Annual	25		0.2	1.6	0.1	75	60	75	5	19
24-hour		1.9	1.6	5.5	1.6	260	150	150	10	37
SO_2										
Annual	6		0.2	1.3	0.7	80		60	2	20
24-hour		3.3	5.3	7.3	5.6	365		260	5	91
3-hour		8.6	4.2	45	29		1,300	1,300	25	512
NO_2[c]										
Annual	20		0.4	36	0.5	100	100			
HC[d]										
3-hour		4.2	2.5	20	11	160	160			

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical Synthane plant/mine combination. Annual average background levels are considered the best estimates of short-term background levels. Concentrations near Gillette are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 16.

[c] It is assumed that all nitrogen oxide from the plant source is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

A. Sulfates

Very little is known about sulfate concentrations likely to result from western energy development. However, one study suggests that for oil shale retorting, peak conversion rates of SO_2 to sulfates in plumes are less than 1 percent.[2] Applying this ratio to plants in the Colstrip scenario results in peak sulfate concentrations of less than 1 microgram per cubic meter ($\mu g/m^3$). This level is well below EPA's suggested danger point of 12 $\mu g/m^3$ for a 24-hour average.[3]

B. Oxidants

Oxidants (which include compounds such as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and bromine) can be emitted from specific sources or formed in the atmosphere. For example, oxidants can be formed when HC combines with NO_x. Too little is known about the actual conversion processes that form oxidants to predict concentrations from power or liquefaction plants. However, the relatively low peak concentrations of HC from the power plant and its associated mine (69 $\mu g/m^3$) suggest that an oxidant problem will probably not result from that source alone. An oxidant problem would more likely result from the combination of background HC and NO_x emitted in the power plant plume. Since background HC levels are unknown, the extent of this problem has not been predicted.

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analysed during the remainder of the project. See: Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment. U.S. Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

[2] Nordsieck, R., et al. Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States. Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975. This study assumed that sulfur dioxide in the plumes was converted to sulfate at the rate of 1 percent per hour independent of humidity, clouds, or photochemically related reaction intensity. Recent work in Scandinavia suggests that acid-forming sulfates arriving in Norway are complex ammonium sulfates formed by a catalytic and/or photochemical process which varies with the season.

[3] Ibid.

In only one of several cases investigated[1] did oxidant formation from coal gasification plants exceed federal standards. However, these cases are not comparable to the Lurgi and Synthane facilities hypothesized in this scenario, and thus levels of oxidants formed from the combination of HC and NO_2 were not predicted. For the Lurgi plant, HC concentrations will be much smaller than those found in the one case in which standards were violated, but the Synthoil plant will produce peak HC concentrations more than 100 times greater than the federal standard. Since NO_2 is also emitted in the Synthoil plant plumes, oxidant formation is probable.

HC concentrations over Colstrip, which are somewhat higher than the federal standard, are also likely to create oxidant problems. Since oxidant formation may occur relatively slowly (i.e. one or more hours), this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Fine Particulates

Fine particulates (those less than 3 microns in diameter) are primarily ash and coal particles emitted by the plants.[2] Current information suggests that particulate emissions controlled by ESP have a mean diameter of less than 5 microns, and uncontrolled particulates have a mean diameter of about 10 microns.[3] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles remaining in plant plumes. The high efficiency ESP's (99-percent removal) in this scenario are estimated to remove enough coarse particulates so that fine particulates will account for about 50 percent of the total particulate concentrations in plant plumes. This percentage applies to the power plant as well as the Lurgi and Synthane gasification processes. However, since just half of the particulate emissions from the Synthoil plant are controlled, only 25-30 percent of its emissions will be fine particulates. Health effects from fine particulates are discussed in Section 12.6.

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[1] Nordsieck, R., et al. *Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States.* Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975.

[2] Fine particulates produced by atmospheric chemical reactions take long enough to form so they occur long distances from the plants.

[3] Fifty percent of the mass is contained in particles this diameter. Enright, S.R., et al. *A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station.* Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

D. Long-Range Visibility

One impact of very fine particulates (0.1-1.0 microns in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light and thus with increased concentrations and/or distances will eventually reduce the contrast between an object and its background below the level required by the human eye to distinguish the object from the background. Estimates of visual ranges for the scenario are based on empirical relationships between visual distance and fine particulate concentrations.[1]

Visibility in the region of this scenario averages about 60 miles. The greatest reduction in average visibility will occur along a north-northwest/south-southwest line extending through Forsyth, Montana. As the facilities in this scenario become operational, the average visibility will decrease only negligibly by 1985, to 58 miles by 1990, to 57 miles by 1995, and to 56 miles by 2000.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although ESP will remove enough particulates for power plants to meet emission standards, stack plumes will still exceed the 20-percent opacity standard.[2] Thus, plumes will be visible at the stack exit and for some distance downwind. Although no opacity standards exist for gasification or liquefaction plants, the Lurgi and Synthane plants both have

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[1] Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." Atmospheric Environment, Vol. 2 (September 1968), pp. 455-64. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

[2] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal unit's heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require removal of 99.8 percent of all plume particulates, which would increase electrostatic precipitators costs.

TABLE 10-9: SALT DEPOSITION RATE

Plant	Average Salt Deposition Rate (pounds per acre per year)		
	1.1 miles[a]	1.1-9.1 miles	9.1-27.8 miles
Lurgi Gasification	16	1	0.03
Power Plant	91	5.8	0.20
Synthane Gasification	8.5	0.6	0.02
Synthoil Liquefaction	23	1.5	0.05

[a] Diameter of circles bounding the area subject to the salt deposition rate.

two stacks which would produce plumes with greater than 20-percent opacity. None of the 24 stacks associated with the Synthoil plant will have a plume exceeding 20-percent opacity.

F. Cooling Tower Salt Deposition

The mist omitted from cooling towers has a high salt content, and will deposit salts downwind from the towers. Estimated salt deposition rates for the facilities in this scenario are shown in Table 10-9. These rates are relatively low and decrease rapidly beyond 1.1 miles. Some interaction of salt deposition from the various plants will occur. For example, one area of overlap between the power, Lurgi, and Synthane plants will receive a cumulative total of 7.4 pounds per acre per year. The effect of salt on the area will depend on soil conditions, rainfall, and existing vegetation.

G. Cooling Tower Fogging and Icing

Fogging potential in the Colstrip area is considered somewhat low since humidities above 90 percent occur only about 30 times per year, with heavy fogs averaging 10 days yearly. However, high incidence of subfreezing temperatures (107 days per year) will cause relatively high icing potentials. This increase in icing could add significantly to ice accumulations and hazardous driving conditions on nearby roads and highways.

10.2.5 Summary of Air Impacts

A. Air Quality

Four new facilities are projected for the Colstrip scenario by the year 2000. The only federal or state ambient standard to be violated by these facilities is for HC, which will be greatly exceeded by the Synthoil plant.

Each of the facilities will exceed several PSD Class I increments. Peak concentrations from the power plant will surpass all allowable Class I increments except for annual particulates. The Synthoil plant will exceed all Class I increments for SO_2, and the Lurgi and Synthane gasification plants will exceed the 24-hour and 3-hour increments for SO_2. Because of these violations, each of the facilities will require buffer zones. The largest buffer zone will be required for the power plant (75 miles), followed by Synthoil (13.4 miles), Lurgi (7.8 miles), and Synthane (7.1 miles).

Population increases in Colstrip will add to existing pollutant levels. Violations of HC standards will be exacerbated by concentrations due solely to urban sources.

Several other categories of air impacts have received only preliminary attention. Our information to date suggests that oxidant and fine particulate problems are likely. Plumes from stacks at all facilities will be visible and, in the case of the power plant, the 20-percent opacity standard may be exceeded. Long-range visibility will be reduced from the current average of approximately 60 miles to 56 miles by the year 2000.

B. Alternative Emission Controls

Pollution concentrations from the power plant would vary if emission control systems with other efficiencies were used. For example, Table 10-10 shows SO_2 pollution concentrations which would result if the plant used only enough control to meet most New Source Performance Standards; that is, if the plant removed only 20 percent of the SO_2 rather than the 80 percent currently hypothesized.[1] These data show that resulting concentrations would violate the federal 3-hour standard and approach the Montana 24-hour standard for SO_2.

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[1] These efficiencies would probably not meet the New Source Performance Standards (NSPS) opacity standard. NSPS do not exist for gasification and liquefaction plants. The Lurgi, Synthane, and Synthoil plants meet all Class II increments in this scenario.

TABLE 10-10. CONCENTRATIONS FROM MINIMAL EMISSION CONTROLS[a]
(micrograms per cubic meter)

SO_2 Averaging Time	Concentration	Standards		
		Primary	Secondary	Montana
Annual	7	80		60
24-hour	225	365		260
3-hour	1,700		1,300	750

SO_2 = sulfur dioxide

[a] These are maximum concentrations which assume 20-percent SO_2 removal, which would meet the federal New Source Performance Standard of 1.2 pounds of SO_2 per million British thermal unit(s) heat input.

Other alternatives are for the plants to increase the efficiency of emission controls or reduce total capacity to meet ambient or PSD increments. The information in Table 10-11 shows that 79-percent SO_2 removal and 98.3-percent particulate removal is necessary to meet all allowable Class II increments.[1]

TABLE 10-11. REQUIRED REMOVAL TO MEET CLASS II INCREMENTS

Pollutant Averaging Time	Removal (%)
SO_2	
Annual	0
24-hour	77
3-hour	79
Particulates	
Annual	80
24-hour	98.3

SO_2 = sulfur dioxide

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[1] These removal efficiencies for sulfur dioxide and particulates are technologically feasible and are actually less than the efficiencies projected in this scenario. More attention will be given to technological feasibility of highly efficient control systems during the remainder of the project.

C. Data Availability

Availability and quality of data have limited the impact analysis reported in this chapter. These factors have primarily affected estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials. Expected improvements in data and analysis capacities include:

1. Improved understanding of pollutant emissions from electrical generation. This includes the effect of pollutants on visibility.

2. More information on the amounts and reactivity of trace elements from coals. This would improve estimates of fallout and rainout from plumes.

10.3 WATER IMPACTS

10.3.1 Introduction

Energy resource development facilities in the Colstrip scenario are sited in the Yellowstone River Basin, a subbasin of the Upper Missouri River Basin. The major water source for this development is the Yellowstone River, although several large tributaries could be used (see Figure 10-3). Annual precipitation in the area is about 14 inches, 3-4 inches of which fall as snow. Thus, the area receives adequate precipitation to sustain local water demands by irrigation, municipal, and industrial users.

10.3.2 Existing Conditions

A. Groundwater

The largest aquifer systems in the Colstrip area are the Madison aquifer, aquifer systems in the coal and sandstone beds of the Tongue River Member of the Fort Union Formation, and alluvial aquifers. Although the Madison aquifer is quite deep in the Colstrip area (about 7,500 feet)[1] it is considered here as a potential water source because of its high pressure (water will rise in a well to within a few hundred feet of the ground surface).

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[1] Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974.

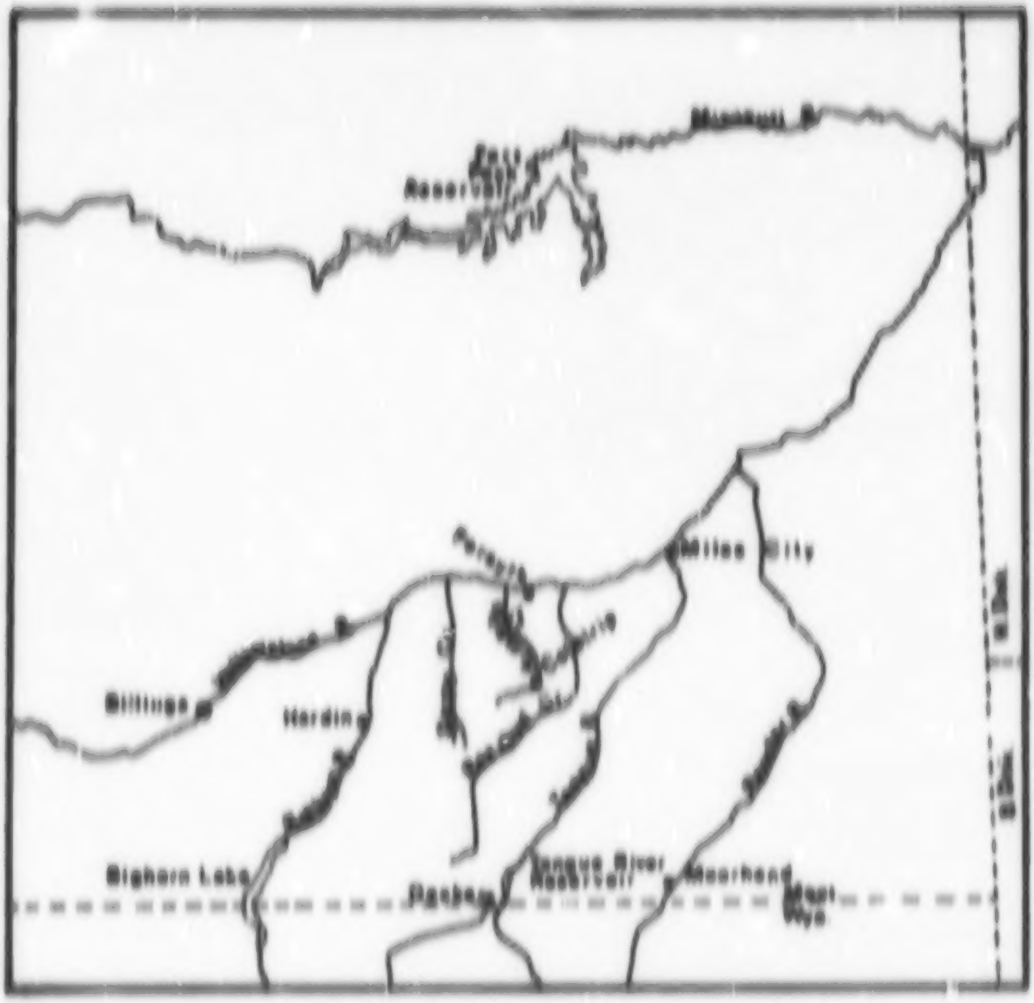

FIGURE 10-3: IMPORTANT HYDROLOGIC FEATURES OF THE COLSTRIP SCENARIO AREA

The closest recharge area of the Madison is along the Bighorn Mountains several miles southwest of Colstrip. Discharge is primarily by upward leakage into overlying strata.

Although large quantities of water are available from the Madison aquifer in the southeastern Montana region, its productivity in the Colstrip area has not been fully evaluated. A test well drilled through this aquifer near Colstrip indicates well productivity may be between 200 and 300 gallons per minute (gpm).[1] The total dissolved solids (TDS) content of the aquifer in the scenario area is about 2,000 milligrams per liter (mg/ℓ). Although deep wells into the Madison aquifer could provide a significant fraction of the water required by energy facilities in the Colstrip area, surface-water and shallow groundwater sources can possibly be developed at less expense.

Aquifers in the Tongue River Member are in sandstone and coal beds that are deposited in alternate layers with shales. The main coal bed aquifer is the Rosebud coal seam, which is the primary source of coal at Colstrip. The water table depth varies but is usually less than 50 feet. Yields of individual wells are usually less than 100 gpm. Recharge is from rainfall and surface streams. Discharge is to seeps and springs on hillsides and as baseflow to the larger streams.

Water quality in the Tongue River aquifer system is highly variable, differing with each sandstone body and coal seam. The median TDS content of 49 water samples from the Tongue River Member was about 900 mg/ℓ,[2] and fresh water is generally less than 1,000 mg/ℓ (1,000-3,000 mg/ℓ is considered slightly saline by the United States Geological Survey [USGS] standards).[3]

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[1] Montana, Department of Natural Resources and Conservation, Energy Planning Division. *Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities*. Helena, Mont.: State of Montana, Department of Natural Resources and Conservation, 1974, v. 3-A, p. 359.

[2] Hopkins, William B. *Water Resources of the Northern Cheyenne Indian Reservation and Adjacent Area, Southeastern Montana*. U.S. Geological Survey Hydrologic Investigations Atlas HA-468. Washington, D.C.: Government Printing Office, 1973.

[3] U.S., Department of the Interior, Geological Survey. *Study and Interpretation of the Chemical Characteristics of Natural Water*. Water Supply Paper 1473. Washington, D.C.: Government Printing Office, 1970, p. 219.

The hardness of Tongue River aquifer water decreases with depth.[1] At present, this groundwater is used only for domestic purposes and livestock watering. Although the aquifer system of the Tongue River Member could not support the energy facilities of the scenario, it could provide water for associated municipal growth.

The alluvial aquifers are along the Yellowstone River and its tributaries, Rosebud Creek and the Tongue River. The alluvium along these rivers is up to 100 feet thick; as much as 60 of that 100 feet is saturated.[2] Wells may yield up to 700 gpm for short periods. Most recharge to and discharge from these aquifers is by interflow with the associated streams. Additional water is lost to vegetation and wells. Water quality in the alluvial aquifers depends on the quality of the river water and the groundwater received from the bedrock formation. The median TDS content of 16 samples taken from alluvial aquifers was about 1,100 mg/l.[3] Present uses of water from alluvial aquifers are limited to supplying domestic and livestock needs. Alluvial aquifers such as those along the Tongue River could provide part of the water for municipal growth but could not support energy facilities.

B. Surface Water

The Colstrip scenario lies within the Yellowstone River Subbasin of the Upper Missouri River Basin. The Yellowstone and Missouri Rivers contribute comparable flows at their confluence on the Montana-North Dakota border. The main tributaries of the Yellowstone flowing through the Fort Union coal region are the Powder, Tongue, and Bighorn Rivers (see Figure 10-3). Flows for these rivers are shown in Table 10-12. The largest reservoir in this part of the Yellowstone basin is Bighorn Lake, which is located on the Bighorn River about 75 miles southwest of Colstrip and has a total storage of 1.3 million acre-feet. The only other

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[1] U.S., Department of the Interior, Geological Survey. Study and Interpretation of the Chemical Characteristics of Natural Water, Water Supply Paper 1473. Washington, D.C.: Government Printing Office, 1970, p. 219; and Renick, B. Coleman. Geology and Groundwater Resources of Central and Southern Rosebud County, Montana, U.S. Geological Survey Water Supply Paper 600. Washington, D.C.: Government Printing Office, 1929, p. 40.

[2] Hopkins, William B. Water Resources of the Northern Cheyenne Indian Reservation and Adjacent Area, Southeastern Montana, U.S. Geological Survey Hydrologic Investigations Atlas HA-468. Washington, D.C.: Government Printing Office, 1973.

[3] Ibid.

TABLE 10-12: SELECTED FLOW DATA FOR THE UPPER MISSOURI AND YELLOWSTONE RIVERS (Flows adjusted to the 1970 level of water resources development)[a]

Subbasin or Tributary	Drainage Area (sq. mi.)	Annual Maximum (acre-feet)	Annual Minimum (acre-feet)	Annual Average (acre-feet)
Upper Missouri River (At Sioux City, Iowa)	314,600	-	-	21,821,000
Upper Missouri River (At Oahe Dam)	243,500	-	-	18,525,000
Yellowstone River	70,115	12,690,000	3,720,000	8,800,000
Powder River	13,415	1,154,000	43,000	516,000
Tongue River	5,400	569,000	37,000	306,000
Bighorn River	22,885	-	-	2,550,000
Clarks Fork	2,783	1,126,000	336,000	767,000
Upper Missouri Tributaries (upstream from confluence with the Yellowstone River)	91,557	-	-	7,276,000

[a] U.S., Department of the Interior, Water for Energy Management Team, _Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin_. Denver, Colo.: Department of the Interior, 1975.

storage facility of significance is the 74,000 acre-ft Tongue River Reservoir about 50 miles south of Colstrip.[1]

Flows in lower-elevation tributaries to the Yellowstone River peak between March and early May. The larger rivers, which depend on the higher-elevation snowpack for their spring runoff flows, peak between mid-June and mid-July. Many of the very small streams have significant discharges from mid-winter to early spring as a result of snowmelt caused by chinook winds or by local thunderstorms in the summer. The soils in the area have relatively low permeability, resulting in low infiltration rates. Runoff averages 0.2-0.5 inch per year.

The Yellowstone River is free-flowing to its confluence with the Bighorn River. Because the flows in the Bighorn are about the same as those of the Yellowstone, and because the Bighorn

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[1] Northern Great Plains Resources Program. _Water Work Group Report_. Billings, Mont.; U.S., Department of the Interior, Bureau of Reclamation, 1974.

River is regulated by Bighorn Lake, the flows in the Yellowstone near Forsyth (where the energy facilities will draw water) are regulated for most of the year.

Water supply and use in Montana is shown in Table 10-13. About 70 percent of total water use is for irrigation. The majority of this water is supplied through state and federal projects, but a portion has been developed privately. Groundwater also is used for irrigation but in negligible amounts compared to surface-water usage.

With the exception of Glendive, municipalities downstream of Miles City use groundwater as a public supply; towns upstream from Miles City use surface water.[1]

The water quality of the Yellowstone Basin rivers is generally good, with the possible exception of the Powder River. Both the Tongue and Bighorn are considered of national importance as sport fishing areas. The Powder River characteristically has high TDS concentrations (3,000-10,000 mg/l, which is considered moderately saline by U.S.G.S. standards). Combined with its tendency to dry up in some stretches in late summer, these TDS levels reduce the Powder River's potential for use as boiler make-up or drinking water. The major source of pollution in all three rivers is agricultural. The representative values of water quality parameters given in Table 10-14 can help individuals evaluate water quality acceptability for specific uses. Although not reported on this table, iron and manganese concentrations in Armells Creek at Colstrip commonly exceed Environmental Protection Agency's Proposed National Secondary Drinking Water Regulations.[2]

10.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements for energy facilities hypothesized for the Colstrip scenario are shown in Table 10-15. Two sets of data are presented. The Energy Resource Development System data are based on secondary sources (including impact statements, Federal Power Commission docket filings, and recently published

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[1] Montana, Department of Natural Resources and Conservation, Energy Planning Division. *Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities*. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974.

[2] U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17143-47 (March 31, 1977).

TABLE 10-13: ESTIMATED 1975 SURFACE-WATER SITUATION FOR SELECTED AREAS IN MONTANA[a]
(1,000 acre-feet)

	Yellowstone River	Upper Missouri River
Average Annual Water Supply		
Modified Inflow to Region[b]	6,305	847
Undepleted Water Yield	4,239	8,398
Estimated 1975 Imports	0	140
Total Water Supply	10,544	9,385
Estimated 1975 Water Use[c]		
Irrigation	776	1,480
M & I Including Rural	43	56
Minerals	10	0
Thermal Electric	1	0
Other[d]	49	155
Reservoir Evaporation	234	369
Total Depletions	1,113	2,060
Estimated Future Water Supply		
Modified 1975 Water Supply[e]	9,431	7,325
Estimated Legal or In-stream Commitments	0	0
Net Water Supply[f]	9,431	7,325

[a] U.S., Department of the Interior, Bureau of Reclamation, *Westwide Study Report on Critical Water Problems Facing the Eleven Western States*. Washington, D.C.: Government Printing Office, 1975.

[b] Inflow reflects the effects of depletions upstream of state lines.

[c] Includes surface water, surface-related groundwater, and mined groundwater.

[d] No depletions are attributed to thermal electric, recreation, and consumptive conveyance losses.

[e] Modified 1975 supply is determined by subtracting estimated total water use from total supply.

[f] Available for future in-stream uses such as for fish, wildlife, recreation, power, or navigation or for consumptive use. Physical or economic constraints could preclude full development.

TABLE 10-14: SELECTED WATER QUALITY PARAMETERS FOR MAJOR SOUTHEASTERN RIVERS
(parts per million by weight)

Parameter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Drinking Water Standard	Typical Boiler Feed Water
Calcium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Magnesium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Sodium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Potassium	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]		
Bicarbonate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Sulfate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chloride	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
TDS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hardness (Ca, Mg)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
pH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Turbidity	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
BOD	[illegible]	[illegible]	[illegible]	[illegible]					
Fecal Coliform (counts/100 ml)	[illegible]	[illegible]	[illegible]	[illegible]					
Dissolved Oxygen	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Sediment (SS)	[illegible]		[illegible]	[illegible]					

BOD = biochemical oxygen demand
Ca = Calcium
Mg = Magnesium
mg/l = milligrams per liter
ml = milliliters
pH = acidity
TDS = total dissolved solids
< = less than

[a] Montana. Department of Natural Resources and Conservation. Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974.

[b] Based on only three measurements.

[c] From unpublished and provisional U.S. Geological Survey data.

[d] U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations," effective June 24, 1977, Fed. Reg. December 24, 1975, Vol. 40, No. 248, pp. [illegible]. These regulations include other standards not given here.

[e] American Water Works Association, Inc. Water Quality and Treatment. 3rd ed. New York, N.Y.: McGraw-Hill, 1971, p. [illegible]. Table [illegible]. Some numbers derived from Table [illegible] assuming concentrating factor = [illegible], high pressure drum type boiler.

[f] Sum of recent U.S. Geological Survey yearly Water Resources Data — Water Quality Records.

[g] Northern Great Plains Resources Program. Water Work Group. Water Quality Subgroup Report. Concurrence draft. Denver, Colo.: U.S. Environmental Protection Agency, Region VIII, 1974.

[h] U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. [illegible] March 31, 1977.

TABLE 10-15: WATER REQUIREMENTS FOR THE ENERGY FACILITIES IN THE COLSTRIP AREA IN THE YEAR 2000

Use	Size	Requirement[a] (acre-ft/yr)	
		ERDS[b]	WPA[c]
Power Generation	3,000 MWe	42,000	37,400
Coal Gasification (Lurgi)	250 MMscfd	7,060	4,820
Coal Gasification (Synthane)	250 MMscfd	10,100	8,370
Coal Liquefaction (Synthoil)	100,000 bbl/day	19,400	10,900
Coal Mining	56.8 MMtpy		1,240

bbl/day = barrels per day   MMtpy = million tons per year
MWe = megawatts-electric
MMscfd = million standard cubic feet per day

[a] Requirements are based on an assumed load factor of 100 percent. Although not realistic for sustained operation, this load factor will generate the maximum water demand for these facilities.

[b] From the Energy Resources Development System Description.

[c] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The load factors assumed in that report were different for different technologies. The water consumption was changed to correspond to a 100-percent load factor in this table.

data accumulations[1]) and can be considered typical consumptions. The Water Purification Associates data are from a study on minimum water use requirements for the Colstrip area and take into account the moisture content of the coal being used and local meteorological data.[2]

Figure 10-4 shows the water consumed for different purposes by the hypothesized energy facilities. As indicated, more water is used for cooling than processing and solids disposal combined. Solids disposal consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

Additional water requirements are associated with the coal mines that will support these facilities. Reclamation efforts will use the majority of the mine water required; dust control, handling, crushing, and service water requirements are estimated to be approximately 1,240 acre-feet per year (acre-ft/yr)[3] or 25 percent of that required for reclamation. However, because the reclamation water requirements are not clearly defined for this specific coal spoil waste under area climatic conditions, Table 10-16 estimates were based on an irrigation rate of 9 inches per year over a 5-year period.[4]

Water supplies for the various scenario energy conversion facilities in the Colstrip area will be imported by individual pipelines from the Yellowstone River as shown in Figure 10-5. The Yellowstone River is the most likely source of water because of its proximity, high flow, and good quality. However, there is

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[1] These energy resource development systems, which are forthcoming as a separate publication, are based on data drawn from: University of Oklahoma, Science and Public Policy Program. *Energy Alternatives: A Comparative Analysis*. Washington, D.C.: Government Printing Office, 1975. Radian Corporation. *A Western Regional Energy Development Study*, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

[2] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[3] *Ibid*.

[4] Differences between water demand of native grasses and average precipitation. See U.S., Department of the Interior, Bureau of Land Management. *Resource and Reclamation Evaluation: Otter Creek Study Site*, EMRIA Report No. 1. Billings, Mont.: Bureau of Land Management, 1975.

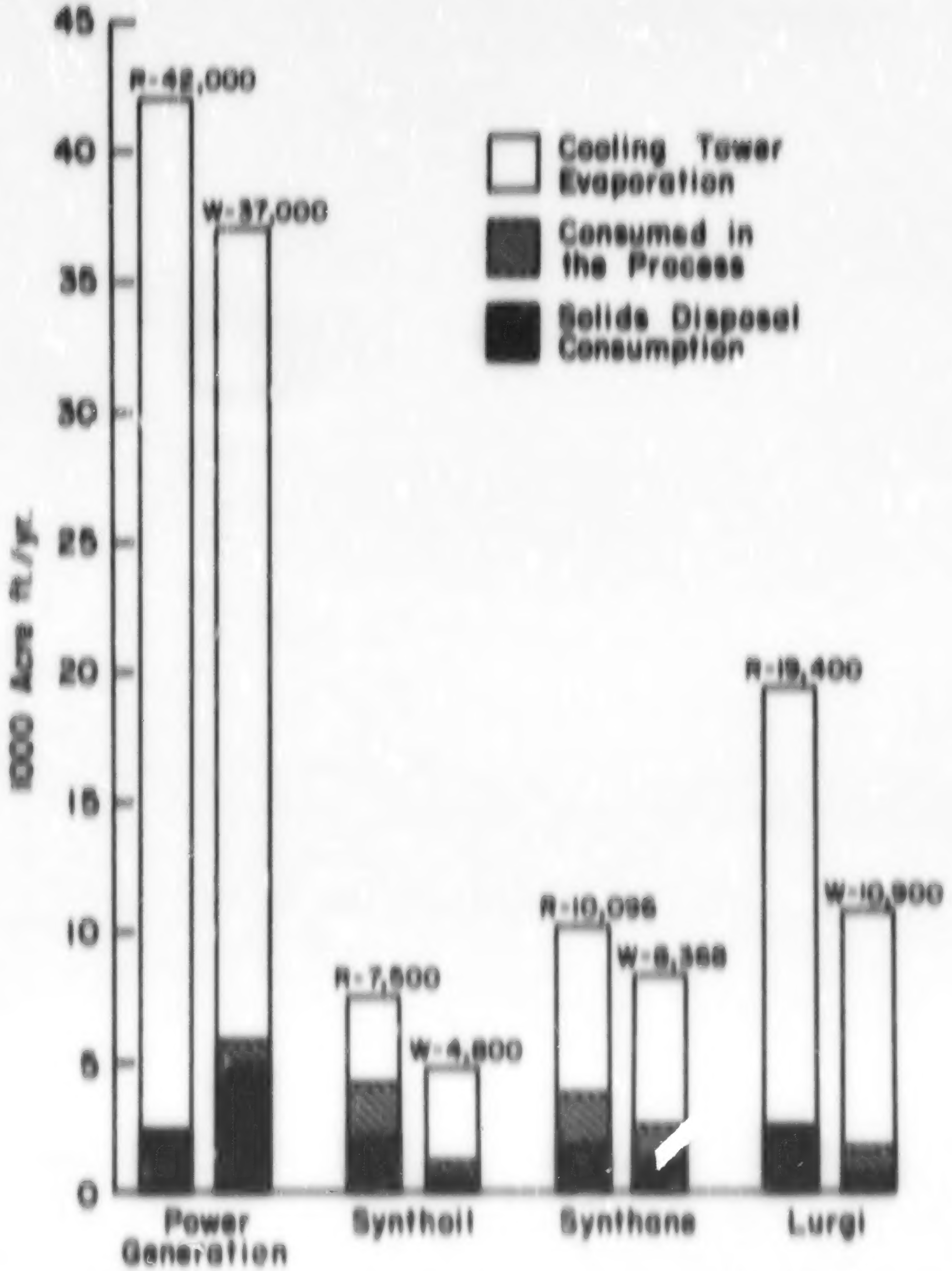

FIGURE 10-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE COLSTRIP SCENARIO

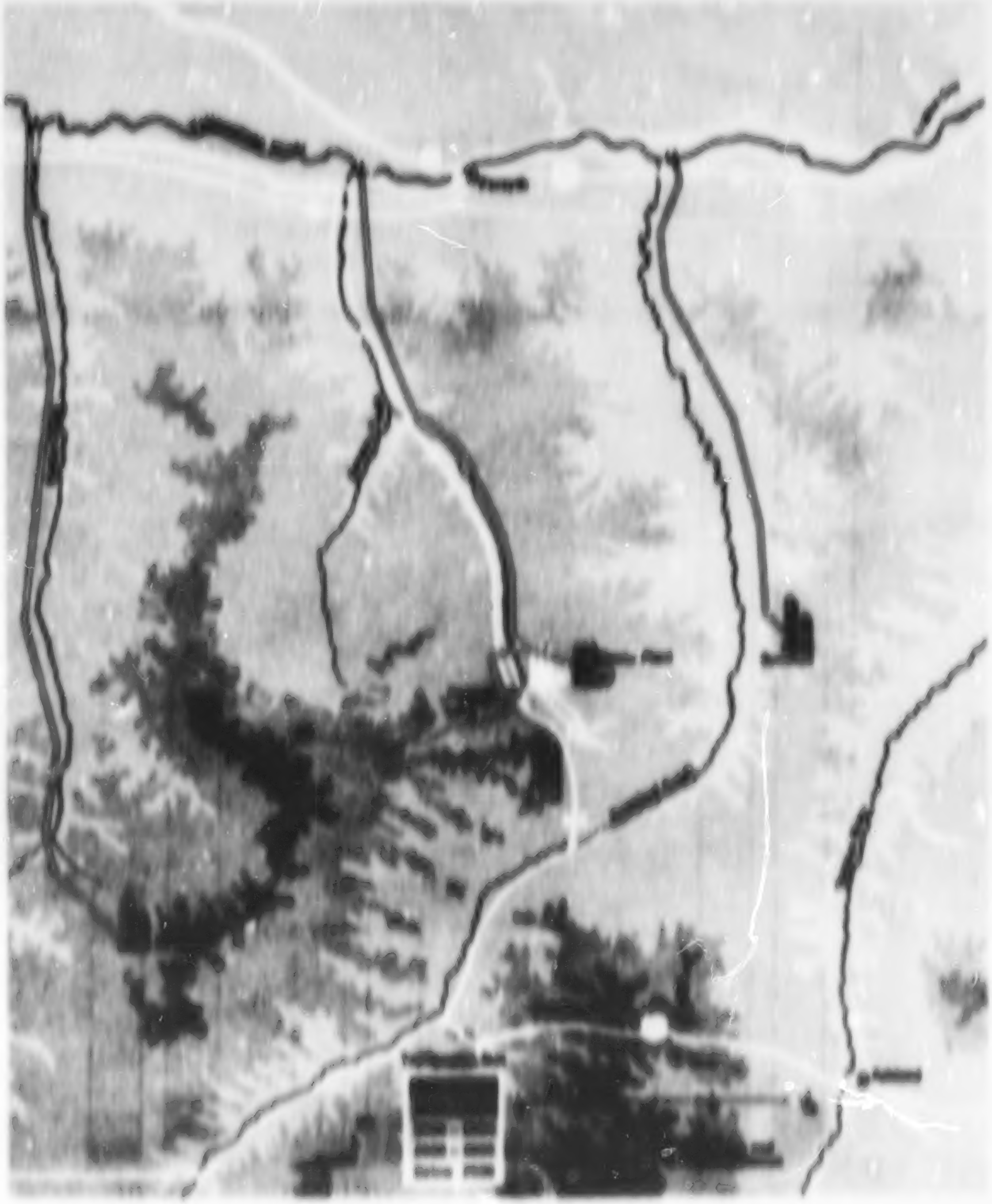

FIGURE 10-5: WATER PIPELINES FOR ENERGY FACILITIES IN THE COLSTRIP SCENARIO

TABLE 10-16: WATER REQUIREMENTS FOR RECLAMATION

Mine	Acres Disturbed Per Year	Maximum Acres Under Irrigation	Water Requirement (acre-ft/yr)
Power Plant	340	1,720	1,290
Lurgi	240	1,180	890
Synthane	240	1,180	890
Synthoil	250	1,250	940
Total	1,070	5,330	4,010

currently a 3-year moratorium on new diversions from the Yellowstone in excess of 20 cubic feet per second (14,000 acre-ft/yr).[1] This moratorium, which will end in 1977, was put into effect to allow Montana time to clear up water rights questions raised by a change in procedures. Since the Montana Water Use Act of 1973, the state has administered all surface-water and groundwater rights through a permit system. Montana is now in the process of determining valid appropriations under the old "right of use" system before approving new rights that might over-allocate Yellowstone River water. When this situation has stabilized, a developer will be able to apply for a new right. Although an old right could be transferred, it might not be recognized or given the same priority under the new system.

B. Municipal Facilities

Assuming that the towns on the Yellowstone River (including Miles City) will continue to use surface water for municipal needs, the projected increases in water supply requirements as a result of energy development (based on population predictions from Section 10.4) are shown in Table 10-17. Rural population growth generally is not expected because of county zoning and land-use practices.

The only municipality in Table 10-14 that will use groundwater as a supply source is Colstrip, where a well field will be developed that will tap aquifers in the Tongue River member. Since only about 300 gpm will be needed by the year 2000, the well field should not be extensive.

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[1] Montana Revised Codes Annotated § 89-8-105 (Cumulative Supplement 1975).

TABLE 10-17: WATER REQUIREMENTS FOR INCREASED POPULATION GROWTH[a]
(acre-feet per year)

Location	1980	1990	2000
Forsyth[b]	1,120	4,256	12,320
Colstrip	245	420	784
Miles City[c]	35	91	322
Billings[c]	56	154	504

[a] Above the 1975 base level; based on 125 gallons per capita per day (gcd).

[b] Based on 1,000 gcd (present consumption during the summer--Montana Water Quality Bureau).

[c] City growth caused by energy development included.

10.3.4 Effluents

A. Energy Facilities

The energy facilities at Colstrip have been designed so that no liquid waste will be returned to the surface-water or groundwater system. All potential pollution areas will have runoff protection systems to intercept and direct natural runoff to either a water treatment plant or a holding pond. Water collected in this manner will be evaporated or will be treated and used as make-up for plant operations. The holding ponds will have dikes and will generally be lined with clay to retard leakage of fluids into the aquifer systems. The on-site water effluents for the facilities are shown in Figure 10-4.

The quantities of solid wastes from the energy facilities hypothesized for the Colstrip area are shown in Table 10-18. The largest quantities of effluents are from ash disposal and flue gas desulfurization. Although the exact make-up of the effluent streams will depend on the technology used, the ash disposal effluent quantity will depend primarily on the ash content of the coal used. The quantity of flue gas desulfurization effluent will depend on the sulfur content of the coal and the fraction of sulfur removed in scrubbing.

TABLE 10-18: RESIDUAL GENERATION FROM TECHNOLOGIES AT COLSTRIP[a]

	Stream Content[b]	Lurgi			Synthane			Synthoil			3,000 MWe		
		Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (tpd)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (tpd)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (tpd)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water in Solids (tpd)
Condensate Treatment Sludge	o	99	22	11	107	22	26	76	26	19	—	—	—
Boiler Demineralizer Waste	s	37	15	2.2	24	11	2	9	4	0.7	2.3	1.1	1.2
Treatment Waste	i	21	11	1.0	33	20	2.6	28	9	1.6	—	—	—
Treatment Waste	-	15	8	1.3	27	17	2.7	40	22	3.2	227	87	21
Flue Gas Desulfurization	-	601	260	52	209	76	29	—	—	—	6,556	2,621	459
Bottom Ash Disposal	i	2,744	2,111	226	427	402	26	6,232	4,712	227	1,112	790	43
Fly Ash Disposal[c]	i	152	109	12	2,403	1,920	82	—	—	—	1,901	1,174	111
Total	-	1,809	2,685	256.3	3,404	1,560	245.8	6,337	4,731	252.3	11,777	4,676	650.2

gpd = gallons per day
MWe = megawatts-electric
tpd = tons per day

[a] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report. For University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S. Environmental Protection Agency, forthcoming. Figures were adjusted to correspond to a load factor of 100 percent. See Appendix B.

[b] s = soluble inorganic; i = insoluble inorganic; o = organic, insoluble.

[c] Dry electrostatic precipitators are assumed to remove the coal fly ash from the flue gas which is then quenched with water for transport via ashes conveyor.

The calculated residuals will be produced in several streams but primarily in two main process streams. The condensate treatment sludge stream will be 80-percent water; the remainder will be primarily insoluble organic waste composed of the dirty plant condensate. This stream will be sent to water treatment where sludge is produced in biotreatment. The other process stream will be boiler demineralizer waste, which is primarily soluble inorganic waste with 50-percent moisture. For this plant, 5.1 tons of wet sludge will be produced per million gallons of water evaporated.

Cooling water treatment waste will be composed of a primarily soluble inorganic fraction and a primarily insoluble inorganic fraction.

Flue gas desulfurization will be accomplished by the wet limestone process in which hydrated calcium sulfate and sulfite ($CaSO_4 \cdot 2H_2O$ and $CaSO_3 \cdot \frac{1}{2}H_2O$) are the two major products. The quantities of solid waste generated were calculated by assuming a 40-percent solids concentration.

Bottom ash is primarily insoluble inorganic waste. Dry-ash furnaces that use pulverized coal are assumed. In these furnaces 20 percent of the ash leaves as bottom ash and the remaining 80 percent leaves as fly ash (except in the Synthoil process in which all of the ash is assumed to come out as bottom ash in the hydrogen plant).

B. Municipalities

The wastewater generated by the population increases associated with energy development is shown in Table 10-19. Rural populations are assumed to use individual, on-site waste facilities (septic tanks and drain fields), and the urban population will require waste treatment facilities. Current treatment practices in affected communities are shown in Table 10-20.

Based on current treatment facility capacities, new facilities will be required in Colstrip before 1980, in Forsyth around 1990, and in Miles City before 2000. These facilities must use the "best practicable" waste treatment technology to conform to 1983 standards and must allow recycling or zero discharge of pollutants to meet 1985 standards.[1] The 1985 standard could be met by using effluents for industrial process make-up water or for irrigating local farmland. Policy issues concerning municipal sewage treatment are discussed in Section 14.3.4.

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[1] Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

TABLE 10-19: INCREASED WASTEWATER FROM POPULATION GROWTH[a]
(million gallons per day)

Location	1980	1990	2000
Forsyth	0.1	0.38	0.1
Colstrip	0.175	0.30	0.56
Miles City	0.025	0.065	0.21
Billings	0.04	0.11	0.36

[a] Above the 1975 base level, based on 100 gallons per capita per day. Rural population is assumed to use septic tanks, so no wastewater is present. Only growth caused by energy development considered.

10.3.5 Impacts

A. Impacts to 1980

Between the present and 1980, the only activity scheduled is the beginning of the construction of the 3,000 megawatts-electric (MWe) power plant and the opening of the associated coal mine.

1. Surface Mines

The opening of the surface coal mine for the power plant will cause disturbances of aquifer systems in the Tongue River Member of the Fort Union Formation. Since the source of the coal, the Rosebud seam, is a large aquifer in the Tongue River Member, mine dewatering will probably be required in most areas. This dewatering may cause aquifer depletion in the relatively low-productivity Tongue River Member. As a result, water levels in nearby wells will be lowered, and some of the springs and seeps on the hillsides may dry up. In addition, the base flow of some of the streams may be reduced or eliminated.

The opening of the coal mine will have some impact on the local surface water. The effect will generally be a result of vegetation removal and soil disturbance. The silt load will be increased in local streams until runoff can be controlled by ponding and settling. Until other uses develop, ponded runoff will be used for dust control and revegetation, with the excess being evaporated. There may also be fugitive spills of lubricants and fuels either in bulk from a storage site or from

TABLE 10-20: WASTEWATER TREATMENT CHARACTERISTICS FOR THE COLSTRIP SCENARIO[a]

Town	Type of Treatment	Design Capacity (MMgpd)	Present Flow (MMgpd)	Per-Capita Flow	Future Plans
Forsyth	2-cell stabilization 8.18 acres	0.54	0.27	100	Abandon present facility—use oxidation ditch and digestion
Miles City	3-cell stabilization	1.18	1.02	106	Upgrade operation of existing system
Colstrip	3-cell stabilization	0.09	0.09	90	None
Billings	New secondary treatment plant September 1976				

MMgpd = million gallons per day

[a] Letter from Department of Health and Environmental Services, State of Montana, 1976.

machine maintenance. These petroleum products will not readily degrade and will contaminate runoff.

2. Energy Conversion Facilities

Although the construction activities associated with the power plant and coal mine are not expected to have an appreciable impact on any groundwater systems on the scenario areas, they will remove vegetation and disturb the soil. Both these activities affect surface-water quality, primarily in the form of sediment load increases. Additionally, the equipment used during construction will require petroleum storage and maintenance facilities. Other areas will be required for storage of materials for the concrete batch plant and other construction-related activities. All these facilities will contaminate runoff. Runoff control techniques will be instituted at all the potential contaminant locations. Runoff will be gathered in a common pond for settling, reuse, and evaporation. As the supply of water to this pond is very intermittent, evaporation may claim most of the water, although some may be used for dust control at aggregate storage sites.

3. Municipal Facilities

Of the 1,456 acre-ft/yr of water required by the population increases associated with the Colstrip scenario, 245 acre-ft/yr for the town of Colstrip will come from the Tongue River Member aquifers. The remainder will come from the Yellowstone River to satisfy needs in Forsyth, Miles City, and Billings (see Table 10-12).

The municipal growth at the Colstrip scenario will be restricted to expansion of existing communities, most of which have municipal sewage treatment facilities.

Septic tanks may pose a significant hazard to groundwater quality in local Tongue River Member aquifers. The projected population increase at Colstrip for the scenario will increase the magnitude of the hazard to groundwater quality.

Miles City, Forsyth, and Billings must increase their wastewater treatment facility capacities to meet the expected needs. As shown in Tables 10-19 and 10-20, wastewater treatment requirements will exceed capacity at Colstrip. Facilities must be expanded or treatment plant effluent will be reduced in quality. Also, treatment levels must be upgraded to meet the requirements of the Federal Water Pollution Control Act (FWPCA) guidelines. This combined effect will be felt most acutely within the smaller communities, and some financial hardship may result.

B. Impacts to 1990

Construction of the 3,000-MWe, coal-fired power plant will continue and its associated coal mine will be opened during the 1980-1985 period. The power plant will go on-line in 1985. In addition, construction will begin on the Lurgi high-Btu (British thermal unit) gasification plant and its associated coal mine after 1985 so that this plant can begin operation by 1990.

1. Coal Mines

The strip mine for the 3,000-MWe power plant will be operating at full capacity by 1985, and a new mine for the Lurgi gasification plant will be opened so that mining can begin in 1990. These two mines will disturb local aquifers in the Tongue River Member and surface waters as described for the preceding decade. Since the Rosebud seam is a significant aquifer in the Colstrip area, mine dewatering will probably be necessary. This dewatering may lead to local aquifer depletion and a resultant lowering of water levels in nearby wells. Springs and seeps on hillsides may dry up, and these may be a significant loss to the base flow of Rosebud Creek. The water from mine dewatering operations will be pumped to the power plant and used as make-up water for cooling towers or will be used for mine operations and for revegetation of spoil material.

Shallow bedrock aquifers in the coal and overburden will be lost in the mine area. Replacing the overburden will not necessarily reestablish aquifers because homogenization of the overburden will change its porosity and permeability. If acid and trace element contaminants are present, they could move laterally and appear as part of the discharge of springs and seeps, thus contaminating these important sources of water for wildlife. Alluvial aquifers along Rosebud Creek may also be contaminated by water from the strip mine, either by water recharging directly from polluted bedrock aquifers or by surface water from contaminated seeps and springs.

2. Energy Conversion Facilities

Only the 3,000-MWe power plant will be operating in the 1980-1990 decade. No appreciable impacts on groundwater systems are expected from the construction of the Lurgi plant. The power plant will draw water from the Yellowstone River at a rate of about 42,000 acre-ft/yr, which is about 0.48 percent of the average river flow at Miles City upstream of the confluence with the Powder River (see Table 10-12).

Runoff will be increased as a result of construction activities at the Lurgi facility. These effects will be similar to those stated previously for power plant construction. Runoff will be decreased at the power plant because the facility, coal-storage piles, and other areas likely to contaminate runoff will have runoff control. This system will collect the runoff and divert it to one of the on-site holding ponds.

The disposal sites for several effluents from the power plant will pose a water quality hazard for shallow aquifer systems. Fluids from liquid waste disposal ponds (sanitary effluent, cooling tower blowdown, etc.) may infiltrate through leaky or ineffective pond liners and enter groundwater systems, thus lowering the quality of the water.

3. Municipal Facilities

About 4,920 acre-ft/yr of additional water will be required by population increases caused by the scenario at Colstrip (Table 10-17). Of this amount, 420 acre-ft/yr will be withdrawn from groundwater sources in the town of Colstrip. This quantity of water, which is equivalent to about 260 gpm, may begin to deplete the local shallow aquifers. Several wells will be required, and local water levels may be lowered.

This scenario assumes that the town of Colstrip will build a municipal sewage treatment plant between 1985 and 1990. Until then, the septic tank and drainfield systems will continue to degrade the water quality of local shallow aquifers. The population influx during the 1980-1990 decade will add considerably to the groundwater quality problems. Much of the water taken from local groundwater supplies will be returned to the shallow aquifers through the septic tanks, but such recycling may have serious public health implications. The natural renovating capacity (primarily filtration by sands and adsorption by clays) of the Tongue River Member may be exceeded with increased septic tank use.

Although the water usage of the municipalities relying on surface water will increase, the amount demanded will still be small compared to the total flow of the Yellowstone. Water requirements for municipalities will increase as more construction workers migrate into the area. Forsyth will have the greatest increase, about 4,250 acre-ft/yr above the 1975 level. Municipalities must also treat an increased wastewater load as shown in Table 10-18. Forsyth will have the greatest increase and will exceed the capacity of its current facilities. Because provisions of the FWPCA restrict pollutant discharge after 1983, the communities affected by growth have the additional problem of effluent disposal. Alternate disposal methods, such as selling the effluent to the energy conversion facilities for use as irrigation water for mine reclamation, will be sought. Therefore, no appreciable impact is likely in local surface waters.

C. Impacts to 2000

The Lurgi high-Btu gasification plant will go into operation in 1990. Construction of the Synthane high-Btu gasification plant and associated coal mine will begin shortly after 1990, and the plant will begin operating in 1995. Finally, construction will begin after 1995 on the Synthoil coal liquefaction plant and its associated coal mine, and the plant will begin operation in 2000.

1. Coal Mines

The mines for the remaining two facilities of the Colstrip scenario (the Synthane and the Synthoil plants) will be opened and in operation by 1999. The effects of these mines, in conjunction with the increased size of the first two mines, will accentuate the effects outlined for the previous decade. The new mine openings and old mine expansion will have a significant effect on local surface runoff. The area of land effectively removed from the various local drainage basins is nearly 35,000 acres. This area may decrease surface-water runoff by as much as 1,350 acre-ft/yr. As a result, the intermittent streams in the mine areas could have significantly different flow patterns. There will be a greater possibility that contaminated groundwater from the mine areas will begin flowing into Armells, Sarpy, and Rosebud Creeks (see Figure 10-3 for stream locations). Although the composition of the inflow and its effect on surface-water quality will vary with location, some noticeable stream water quality changes will probably occur during the scenario period.

2. Energy Conversion Facilities

The groundwater and surface-water impacts of the power plant and the Lurgi plant will continue as described for the preceding decade. The impacts of the Synthane plant are expected to be quite similar but additive to those of the two plants already in existence.

The combined facilities will be withdrawing about 59,600 acre-ft of water annually during this decade. This is approximately 0.7 percent of the average annual flow and 18 percent of the minimum flow of record in the Yellowstone River at Miles City upstream of the confluence with the Powder River. This withdrawal will probably not have a significant impact on the Yellowstone River.

The effluent generated by the Synthane plant will not be greatly different from that generated at the power plant and Lurgi gasification plant. Thus, the only changes in the previously described impacts on local aquifer systems and surface water should be minor increases.

3. Municipal Facilities

By the year 2000, the town of Colstrip will withdraw about 780 acre-ft/yr (480 gpm) from local groundwater resources. After 1990, the town will be using a municipal sewage treatment facility; thus, none of this water will be returned to shallow aquifers through septic tank systems. The result will likely be depletion of local shallow aquifers as described for the preceding decade.

A total of 13,930 acre-ft/yr of surface water above the 1975 level will be required by Forsyth, Miles City, and Billings. This amount of water should not significantly affect flow in the Yellowstone River. Wastewater treatment plant capacity must be expanded from the 1975 base level by a factor of 10 for Miles City and Forsyth, and the capacity at Colstrip must be tripled. Thus, the communities will probably have substantial problems in funding and constructing new treatment plants on an appropriate schedule, and package treatment will probably be used as a stop-gap measure. Because pollutants from municipal facilities will not be discharged into surface streams, there will not be any significant impacts on local watersheds.

A. Impacts After 2000

All four coal conversion facilities will continue to operate after 2000, and their impacts will be much the same as those described for earlier decades.

The mines will continue to have long-range impacts on groundwater systems after mine operations cease, despite the reclamation measures that will be undertaken for restoration of surface uses of the land. The overburden that is returned to the mine will have aquifer characteristics quite different from the original, undisturbed overburden.

The total surface-water withdrawal from the Yellowstone will be about 83,000 acre-ft/yr. This quantity is equivalent to about 1.1 percent of the average annual flow and about 12 percent of the extreme low flow of record in the Yellowstone River at Miles City above the confluence with the Powder River. The amount of water being used is significant during low-flow periods, and the effect on the Yellowstone River may be appreciable.

The evaporative pond dikes which have been maintained during plant operation will receive no maintenance after shutdown. These dikes could lose their protective vegetation, erode, and eventually be breached. Subsequently, the materials within the pond site will erode and enter the surface-water system. The salt concentrations may be high enough to cause damage to local aquatic ecosystems. The addition of trace materials and solids from the ash disposal and tailings ponds will have a similar adverse effect.

Population associated with the scenario facilities will remain relatively constant after 2000. The population increases for all the scenario facilities will likely be permanent; thus, the water requirements will continue indefinitely. The problem of potential aquifer depletion caused by groundwater withdrawals at the town of Colstrip is likely to continue.

Since septic tank and drainfield systems will have been replaced by municipal sewage treatment plants by 2000, no continued threat to groundwater quality is expected from septic tank sources. However, infiltration of contaminated urban runoff will continue, and will increase if the size of the urbanized areas increases. This contaminated recharge water will continue to lower the quality of groundwater after 2000.

10.3.6 Summary of Water Impacts

The coal mines will have an impact on both surface water and groundwater in the Colstrip area. A significant portion of the local groundwater may be removed by mine dewatering activities. This depletion could decrease the groundwater supply to surface streams and to springs and seeps. After mining has been completed, the mine area will be reclaimed and revegetated. However, the previous aquifer characteristics will not be reestablished. Because of this factor, it is unlikely that spring and seep flows will return to their previous conditions. Surface runoff will be affected by a change in infiltration rate in the reclaimed areas. Depressions that will hold water may be created in the recontouring process, and these may be beneficial both to groundwater recharge and wildlife.

The energy conversion facilities will require about 81,000 acre-ft of water annually. This value is cumulative over all the energy conversion facilities and their support facilities. The local impact of surface-water withdrawal on water availability appears not to be a major issue for the Yellowstone River except during extreme low-flow periods. The groundwater withdrawals caused mainly by mine dewatering may cause depletion of flow to springs and seeps.

Runoff will be increased during facilities construction, and although it will diminish after the facilities are completed, it will still be measurably higher than before construction. Trapping of this runoff to insure against water quality deterioration could decrease the flows in local streams.

The plant effluents will be discharged to diked evaporative ponds. After the energy conversion plants are decommissioned, the dikes may erode and allow the internal solids to wash into the natural streams. Additionally, pond liner integrity may fail to provide seepage protection after a period of time. Degradation of both surface water and groundwater could result from lack of maintenance of the evaporative ponds.

The impact of energy development on municipal water facilities can be significant, depending on the size of the communities involved. Larger capacity treatment facilities will be required for water supply and wastewater treatment. The municipal water supply requirements will not put a great demand on the surface water resources. Wastewater effluent may be recycled to industries, minimizing effluent impacts. Otherwise, some form of land application would be a likely alternative.

Identification and description of several water impacts has been limited by available information. Missing data includes detailed information about process streams (needed to identify the composition of discharges to settling ponds) and about the rate of movement of toxic materials through pond liners (needed to estimate the portions that might reach shallow aquifers). More quantitative information will be sought during the remainder of the project so that these potential impacts can be properly evaluated.

10.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

10.4.1 Introduction

The primary area of social, economic, and political effects in the Colstrip scenario will be Rosebud County, Montana and, to a lesser extent, the cities of Billings and Miles City. Most of the effects anticipated will result either directly or indirectly from population changes.

10.4.2 Demography and Social Infrastructure

Rosebud County covers 5,037 square miles and had a 1975 population of approximately 8,600 people. The resulting population density of 1.69 persons per square miles is low in comparison with the 1970 Montana average of 4.77 persons per square mile. The county's population has increased since 1970 after a period of relative stability; most of the growth has occurred in Colstrip and Forsyth (see Table 10-21). In 1970, the Northern Cheyenne Indian Reservation in the southern portion of Rosebud County accounted for 1,700 people or about 20 percent of the county's population.

Agriculture dominates the Rosebud County economy, accounting for 33 percent of all earned income in 1972 (the average for Montana was 19.7 percent). The average size ranch or farm was 8,626 acres in 1974. The proportion of farm income from ranching

TABLE 10-21: POPULATION OF ROSEBUD COUNTY, COLSTRIP AND FORSYTH, 1940-1975

Year	Rosebud County	Colstrip	Forsyth
1975[a]	8,500	3,000	2,500
1974		2,650	2,950
1973	6,959	1,800	2,700
1970	6,032	422	1,873
1960	6,187	439	2,032
1950	6,570	553	1,906
1940	6,477	b	1,696

Sources: U.S., Department of Commerce, Bureau of the Census, County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972; University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974; Westinghouse Electric Corporation, Environmental Systems. Colstrip Generation and Transmission Project: Applicant's Environmental Analysis. 1973; Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[a] Estimated.

(livestock income) is higher than the state average: 75.9 percent compared to 63.6 percent. (The distribution of employment by industry in 1970 is shown in Table 10-22.) However, recent development related to power plant construction has altered this pattern by adding substantially to the construction employment proportion.

TABLE 10-22: EMPLOYMENT DISTRIBUTION IN ROSEBUD COUNTY, 1970

Industry	Number	Percentage
Total Civilian Labor Force	2,346	100
Total Employed	2,238	95.4
Agriculture	497	22.2
Contract Construction	116	5.2
Manufacturing	175	7.8
Wholesale and Retail Trade	316	14.1
Services	81	3.6
Education	257	11.5
Government	553	24.7
Other	243	10.9
Total Unemployed	108	4.6

Source: U.S., Department of Commerce, Bureau of the Census. County and City Data Book, A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972, p. 294.

As shown in Figure 10-6, the county's road network is more developed in an east-west direction, focusing on Billings 100 miles to the west and Miles City to the east. Both the Burlington Northern (formerly Northern Pacific) and the Chicago, Milwaukee, St. Paul, and Pacific Railroads cross the county eastward, running through Forsyth. A spur line runs south through Colstrip.

Rosebud County is governed by a board of three elected county commissioners. There is currently no county charter, but one is being developed by a study commission elected in 1975. A county planning board was created in January 1974, and a master plan was to be completed by late 1976. Law enforcement consists of one sheriff with deputies in Forsyth (the county seat), Colstrip, Ashland, and Birney.

Colstrip is an unincorporated community owned by Western Energy Company, a subsidiary of Montana Power Company.[1] Most basic municipal services, such as streets, water and sewer facilities, have been provided by the company.[2] The county

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[1] Colstrip has be[illegible] company-owned town since it was founded by Northern Pacific Railroad in 1923. It was sold to Montana Power in 1959.

[2] Current sewage treatment facilities consist of septic tanks and drainfield systems.

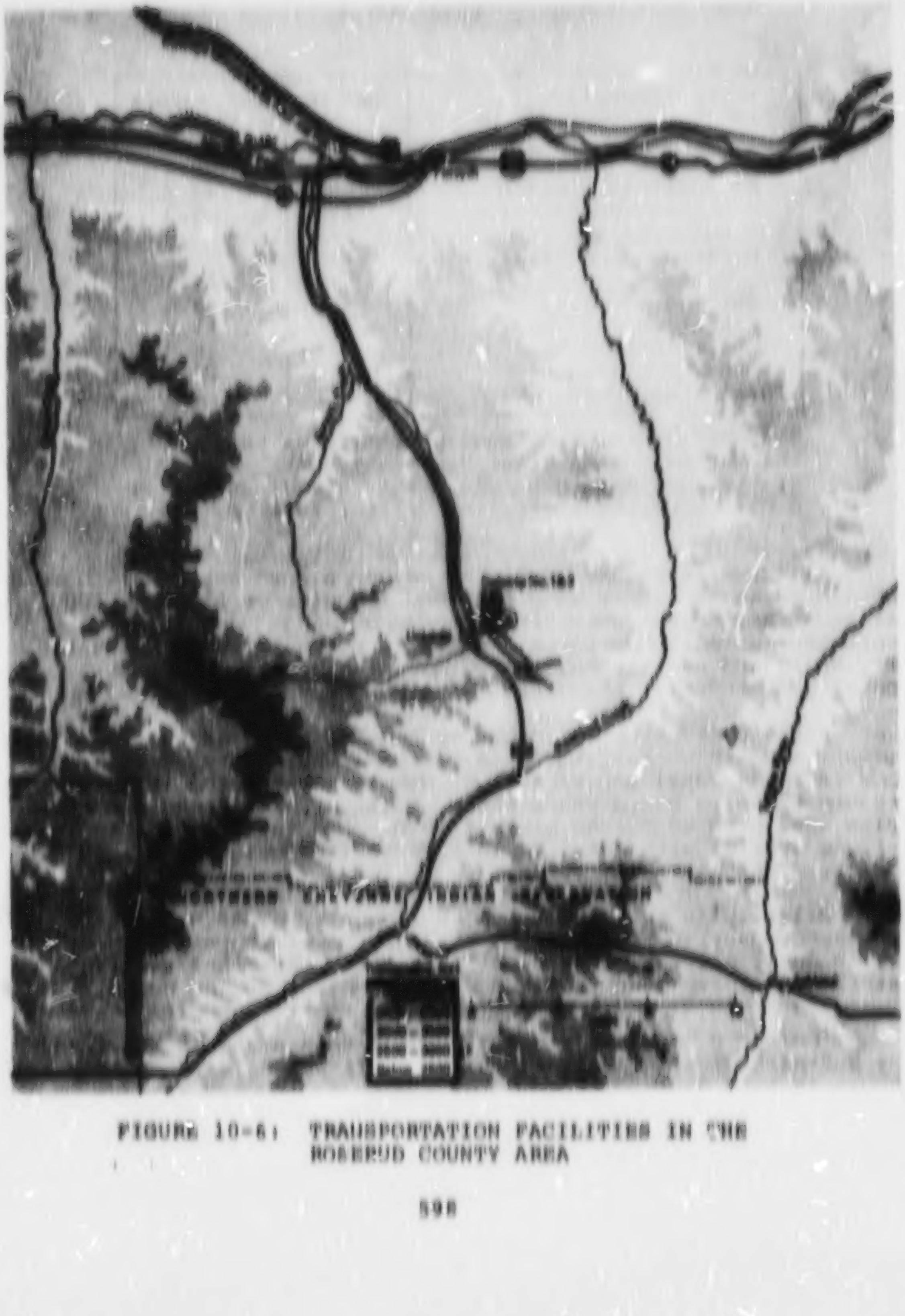

FIGURE 10-6: TRANSPORTATION FACILITIES IN THE ROSEBUD COUNTY AREA

planning board has taken an active role to assure that the town of Colstrip meets all county zoning and building requirements. A town council has been formed to provide resident input to Western Energy Company planners. There were no full-time physicians or dentists in Colstrip in 1975; since then, a clinic facility has been opened with a full-time staff.

Forsyth, the county seat and only incorporated town in Rosebud County, is governed by a mayor and four councilmen. There is no planning department, and most of the planning is done by the city through the use of consultants. Forsyth has both city-owned and operated water and sewage treatment systems, and expansion of the water system is now under way.

10.4.3 Population Impacts

The first major impact on the Rosebud County area from the scenario will be from construction workers associated with the power plant complex beginning in 1977 (Table 10-23). Construction activity in the scenario is scheduled to end in 2000, although employment in construction is minimal in 1985 and 1990.[1] The population estimates explicitly take into account the major market centers of eastern Montana, Billings and Miles City, as well as settlements in Rosebud County (Figure 10-7).

The projected population of Rosebud County is expected to increase more than three-fold to over 27,000 by 2000.[2] The peak population occurs in 1993 in all parts of the county; a slightly smaller short-term peak occurs in 1988. Ashland will receive the most severe impact because of its current small size; its 1988 peak is nearly 10 times its present size of 500. Forsyth and Colstrip remain over 5,000 population after 1986 with occasional peaks during construction activity. The projections reported here effectively consider Colstrip as more similar to other towns. However, its past and present ownership by Western Energy Company could preclude additional population from settling there. If Colstrip is incorporated by the mid-1980's, the populations in Table 10-22 are more realistic.

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[1] Population changes were estimated by means of an economic base model, the employment data from Table 10-23, and the multipliers in Tables 10-24 and 10-25.

[2] Because the Northern Cheyenne Reservation is not the site of coal development in this scenario, estimates of Indian employment are difficult to make. About 200-300 Indians may be directly employed, and out-migration is likely to be slowed. The Northern Cheyenne population is included in the "other" category in Table 10-26.

TABLE 10-23: CONSTRUCTION AND OPERATION EMPLOYMENT FOR COLSTRIP SCENARIO, 1975-2000

Year	Construction	Operation	Total
1975			
1976			
1977	40	0	40
1978	420	0	420
1979	900	0	900
1980	1,350	0	1,350
1981	2,280	0	2,280
1982	2,750	110	2,860
1983	2,200	380	2,580
1984	890	490	1,380
1985	70	990	1,060
1986	820	990	1,810
1987	2,890	990	3,880
1988	4,890	1,260	6,150
1989	2,830	1,260	4,090
1990	70	2,130	2,200
1991	820	2,130	2,950
1992	2,890	2,130	5,020
1993	4,920	2,400	7,320
1994	3,090	2,400	5,490
1995	1,010	3,270	4,280
1996	2,070	3,270	5,340
1997	2,380	3,270	5,650
1998	1,730	3,540	5,270
1999	640	4,180	4,820
2000	0	5,100	5,100

Source: Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975.

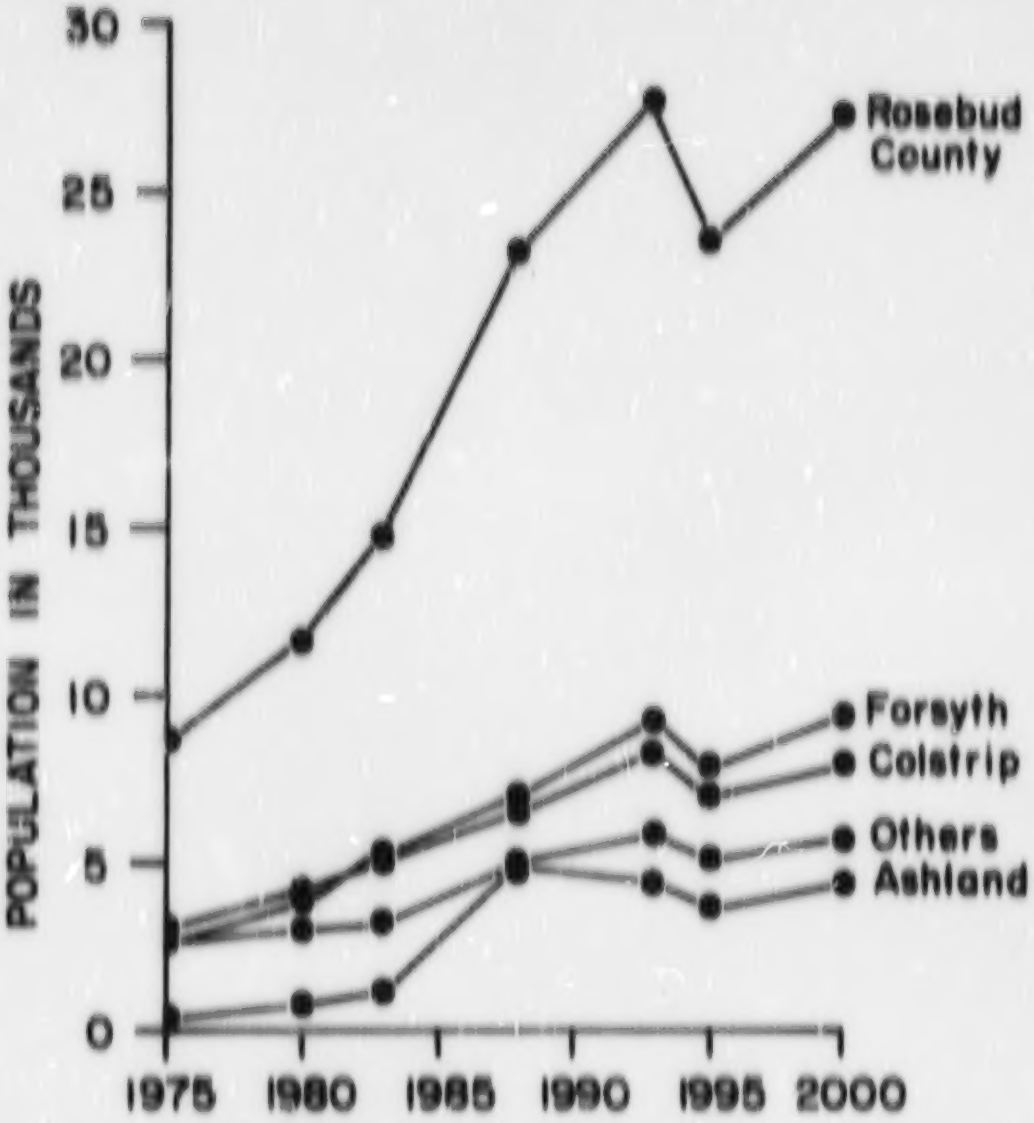

FIGURE 10-7: POPULATION ESTIMATES FOR ROSEBUD COUNTY, 1975-2000

TABLE 10-24: EMPLOYMENT AND POPULATION MULTIPLIERS FOR COLSTRIP SCENARIO POPULATION ESTIMATES

Service/Basic Employment Multipliers[a]		
Location	Construction	Operation
Rosebud County	0.2	0.3
Miles City	0.1	0.15
Billings	0.15	0.35
(Regional Total)	(0.45)	(0.80)

Population Employee Multipliers[b]	
Construction	2.05
Operation	3.1
Service	3

[a] These values were chosen after examining several studies concerned with population impacts in the Northern Great Plains including Polzin, Paul E. *Water Use and Coal Development in Eastern Montana*. Bozeman, Mont.: University of Montana, Joint Water Resources Research Center, 1974; White, Sandie V. *The Decker-Birney-Ashland Area and Coal Development: An Economic Study*. Missoula, Mont.: University of Montana, Bureau of Business and Economic Research, 1975; Montana, Department of Natural Resources and Conservation, Energy Planning Division. *Final Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities*. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, pp. 130-131; U.S. Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974; University of Denver, Research Institute. *The Social, Economic, and Land Use Impacts of a Fort Union Coal Processing Complex*. Final Report for U.S. Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975, FE-1526, pp. 27-49; Erickson, Ronald E. "Social Impacts of Coal Gasification or a Practical Joke," in Clark, Wilson F., ed. *Proceedings of the Fort Union Coal Field Symposium*, Vol. 4: *Social Impact Section*. Billings, Mont.: Eastern Montana College, 1975, pp. 481-91; Johnson, Maxine C., and Sandie V. White. *Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

[b] Adapted from Mountain West Research. *Coal Gasification Worker Profile*. Final Report. Washington, D.C.: Old West Regional Commission, 1975. These multipliers are aggregates which balance such factors as single-person households, large families, and working spouses.

TABLE 10-25: ASSUMED POPULATION ATTRACTION OR CAPTURE RATES USED TO ALLOCATE POPULATION WITHIN ROSEBUD COUNTY

	Forsyth	Colstrip	Ashland	Other
Energy Population				
1975-1985	.40	.40	.10	.10
1986-1990	.20	.20	.40	.20
1991-2000	.30	.30	.20	.20
Service Population				
1975-1985	.75	.15	.10	
1986-1990	.40	.20	.30	.10
1991-2000	.40	.20	.20	.20

TABLE 10-26: POPULATION ESTIMATES FOR ROSEBUD COUNTY, 1975-2000

Year	Rosebud County	Forsyth	Colstrip	Ashland	Other[b]
1975	8,600	2,500	3,000	500	2,600
1980	11,620	3,820	4,080	790	2,930
1981	13,530	4,690	4,770	980	3,090
1982	14,850	5,290	5,210	1,100	3,250
1983	14,700	5,270	5,130	1,090	3,210
1984	12,740	4,440	4,380	890	3,030
1985	12,690	4,510	4,280	880	3,020
1986	14,060	4,880	4,610	1,450	3,120
1987	18,430	5,870	5,460	3,020	4,080
1988	23,200	7,010	6,430	4,810	4,950
1989	19,680	6,260	5,740	3,400	4,280
1990	17,160	5,830	5,250	2,340	3,740
1991	18,710	6,120	5,890	2,640	4,060
1992	22,860	7,640	6,870	3,470	4,880
1993	27,660	9,170	8,220	4,420	5,850
1994	24,500	8,200	7,310	3,790	5,200
1995	23,350	7,900	6,910	3,550	4,990
1996	25,540	8,600	7,530	3,990	5,420
1997	26,270	8,840	7,740	4,130	5,560
1998	25,910	8,750	7,630	4,050	5,480
1999	25,770	8,750	7,550	4,020	5,450
2000	27,170	9,240	7,910	4,350	5,670

[a] Given the development in this scenario, the population increases are within a ±25 percent range of expected conditions. For example, Rosebud County's population in 2000 should be between 22,500 and 31,800.

[b] Other includes a rural population of about 1,800 throughout the period, as well as townsites such as Rosebud, Lame Deer, and Birney.

Outside Rosebud County, Miles City and Billings will receive a noticeable amount of service industry growth stemming from wholesale and retail sales to Rosebud County residents.[1] Miles City, east of Forsyth, should grow in population by 5,800 or 62 percent by the year 2000. Expected growth in the Billings area of 17,800 is only about 27 percent of its current population. The bulk of the overall population increase from the scenario is expected to take place within Rosebud County where nearly all of the cyclical impact occurs.[2]

Age-sex breakdowns of the projected population of Rosebud County help to indicate the housing and educational needs of the area. From the county's 1970 age-sex distributions, new immigrants were assumed to fall into categories derived from studies of energy-impacted communities.[3] The resulting age-sex distribution (Table 10-27) shows particular increases in the 25-34 age groups and a high proportion of school-age children through 1985. A disparity between males and females should diminish throughout the energy development period.

10.4.4 Housing and School Impacts

Housing demand and school enrollment can be estimated by employing the information in Tables 10-26 and 10-27 and by assuming that the 6-13 age group is elementary school enrollment and the 14-16 age group comprises secondary school enrollment

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[1] University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 61-69; Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: University of Montana, Joint Water Resources Research Center, 1974.

[2] When construction employment does not carry over from year to year, the employees, their families, and one-half of the associated service population is assumed to leave the area. Given the large amount of energy construction activity which might occur in the West, this assumption is as reasonable as its alternatives.

[3] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 33-38.

TABLE 10-27: PROJECTED AGE-SEX DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000

Age	1975	1980	1985	1990	1995	2000
Females						
65 and over	.051	.037	.033	.024	.018	.016
55-64	.039	.035	.031	.026	.024	.022
35-54	.102	.102	.098	.095	.094	.094
25-34	.057	.090	.113	.143	.158	.172
20-24	.035	.043	.042	.045	.048	.046
17-19	.025	.027	.027	.028	.029	.030
14-16	.029	.023	.023	.020	.018	.017
6-13	.092	.072	.075	.066	.059	.056
0-5	.064	.051	.055	.050	.046	.045
Total	.494	.480	.496	.498	.494	.499
Males						
65 and over	.050	.036	.033	.023	.017	.015
55-64	.043	.041	.033	.028	.026	.027
35-54	.113	.118	.105	.100	.100	.096
25-34	.059	.104	.115	.144	.163	.172
20-24	.027	.042	.037	.042	.047	.047
17-19	.020	.026	.024	.026	.020	.028
14-16	.038	.029	.029	.024	.020	.019
6-13	.095	.074	.076	.067	.059	.057
0-5	.060	.049	.052	.049	.045	.044
Total	.516	.520	.504	.502	.506	.501

Source: Table 10-32 and data adapted from Mountain West Research. Construction Worker Profile, Final Report, Washington, D.C.: Old West Regional Commission, 1976, pp. 33-38.

(Table 10-28, Figure 10-8). The demand for housing is twice the 1975 level by the mid-1980's, then doubles again during the peak construction activity around 1993 (Table 10-28). At least 600 extra homes would be needed for peak population above the year 2000 level.

In accordance with the experience of other energy-impacted areas, much of the housing for development workers will be provided by mobile homes. About 39 percent of Rosebud County's housing in 1974 was made up of mobile homes, up from about 9.5

TABLE 10-28: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN ROSEBUD COUNTY, 1975-2000

Year	Households[a]	Elementary[b]	Secondary[c]
1975	2,510	1,560	510
1980	3,960	1,700	600
1983	4,470	2,220	760
1988	7,330	3,090	1,020
1993	8,900	3,480	1,130
1995	7,680	2,760	890
2000	8,300	3,070	980

[a] Estimated from number of males aged 22 and over, representing an aggregate of single-person households and families. Estimates should be seen as medians in a 25-percent error range.

[b] Ages 6-13, resulting in somewhat low estimates; the upper end of the range should be 20-25 percent above these figures.

[c] Ages 14-16, resulting in somewhat low estimates; see b above.

percent in 1970.[1] More than fifty percent of the newcomers will be forced to live in mobile homes, and this percentage will be higher at Colstrip than at Forsyth.[2] These trends were begun in connection with construction activity on Colstrip power plant Units 1 and 2, and will continue in the scenario development here. Any single- and multi-family units are likely to be located primarilly at town sites within the county, although only Forsyth and Colstrip currently provide municipal water service. Thus, development in the Ashland vicinity must rely on septic tanks.

School enrollment impacts will be relatively minor through 1983, with a 42-percent elementary increase and a 49-percent

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[1] U.S., Department of Agriculture, Committee for Rural Development. *1975 Situation Statement: Rosebud-Treasure Counties*. Forsyth, Mont.: Department of Agriculture, 1975, pp. 65-74.

[2] Mountain West Research. *Construction Worker Profile, Community Report: Forsyth and Colstrip, Montana*. Washington, D.C.: Old West Regional Commission, 1976.

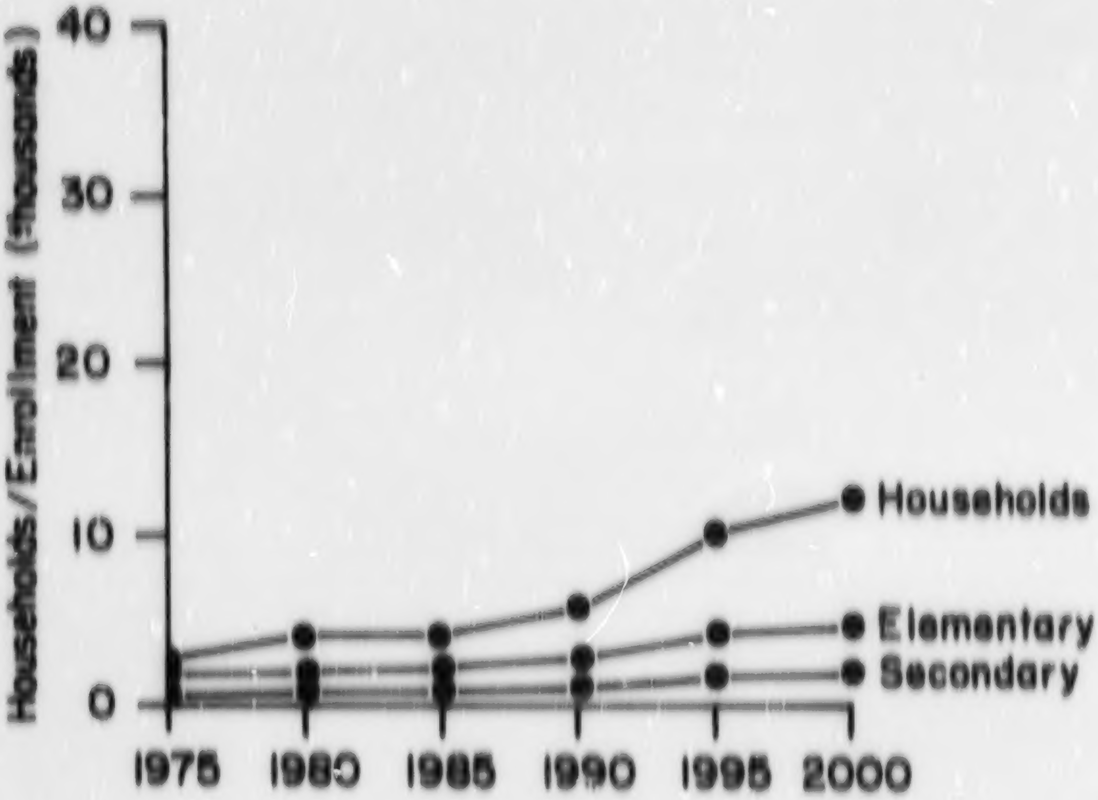

FIGURE 10-8: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY, AND SECONDARY SCHOOL CHILDREN IN ROSEBUD COUNTY, 1975-2000

secondary increase over 1975 levels (Table 10-28). From 1983 to 1993, enrollments will nearly double at both school levels. The enrollments peak in 1993, and the 2000 enrollments are very close to the 1988 levels. This suggests that temporary facilities could accommodate the 1990's construction bulge at much less expense than permanent structures. About 220 new classrooms will be needed for the 1993 peak, which is about 25 more than will be needed for the 2000 enrollment (Table 10-29). Capital expenditures for new schools should be below $6.5 million, especially if modular-type classrooms are used for peak enrollments; annual operating expenditures should double (in constant dollars) by 1993.[1] The distribution of these needs within the county is suggested by the population distribution in Table 10-26.

10.4.5 Land-Use Impacts

The energy facilities involved in this scenario will occupy about 54 square miles of Rosebud County, or just over 1 percent of the county's total land area. Land currently leased for coal as of July 1974 covers 3.86 percent of the county, indicating a potentially greater number of surface mines.[2] Energy-related population increases and resultant urban development will require a relatively negligible portion of land and will be located almost entirely at existing towns. Zoning and subdivision regulations in the county will prevent the rural settlement scatter that is occurring elsewhere in the West.

The actual change in land use will be drastic in some local areas. Over 92 percent of Rosebud County is cropland, grazing land, or woodland, and any coal mining activity would necessarily reduce the agricultural acreage. Recreation activities, especially hunting, will probably increase along with the expected population growth, involving conflicts between landowners and those who use the area for recreational purposes. Finally,

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[1] These estimates may be compared with U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 230-252.

[2] U.S., Department of Agriculture, Committee for Rural Development. *1975 Situation Statement: Rosebud-Treasure Counties*. Forsyth, Mont.: Department of Agriculture, 1975, pp. 46-47.

TABLE 10-22: SCHOOL FINANCE CONDITIONS FOR AFFECTED COUNTY DISTRICTS, 1975-2000
(In 1975 dollars)

	1975	1980	1983	1985	1990	1995	2000
Enrollment Increase over 1975	2,070	2,300	2,980	4,320	4,610	3,650	4,050
Classrooms (at 21 per room)	96	110	142	206	220	174	193
Capital Expenditure Increase over 1975 (millions of dollars)[a]		0.58	2.28	5.10	6.35	3.95	4.95
Annual Operating Expenditure Increase (millions of dollars)[b]		2.88	3.73	5.34	5.76	4.56	5.06

[a] An average of $2,500 per pupil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971. This figure is a high estimate where modular or other inexpensive construction is used.

[b] Based on an average of $1,250 per pupil per year. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

additional land bordering on coal mining areas may be rendered unsuitable for grazing as a result of odors, pollution, dust, and noise.[1]

10.4.6 Economic and Fiscal Impacts

A. Economic

Rosebud County's economy currently is dominated by agriculture, especially ranching which accounted for 33 percent of all 1972 earnings.[2] Coal mining and conversion activities will undoubtedly shift the major portion of income to the extraction and utilities sectors, although most of the land will remain agricultural. Local service and government employment will also expand, especially at Forsyth, the county seat. Based on new employment opportunities in Rosebud County, the overall income distribution will change considerably over the course of the scenario (Table 10-30; Figure 10-9). Largely because of the higher paying jobs in energy industries, the $15,000-20,000 category should expand considerably. However, both the distribution and the median income are strongly influenced by construction activity, as evidenced by the up-and-down effect during the 1980-1990 period. In addition, short-term inflation will reduce purchasing power at times, a fact disguised by the constant dollar computation.

The scenario energy developments will result in local business increases similar to but substantially greater than the increases resulting from the recent construction of Colstrip Units 1 and 2. However, Billings and Miles City should receive much of the wholesale and retail expansion from Rosebud County population

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[1] Montana, Department of Natural Resources and Conservation, Energy Planning Division. *Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities.* Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, pp. 767-770.

[2] U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." *Survey of Current Business*, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 10-30: PROJECTED INCOME DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000 (in 1975 dollars)

	1975	1980	1985	1990	1995	2000
Less than 4,000	.202	.130	.168	.117	.090	.086
4,000-5,999	.117	.078	.090	.074	.059	.058
6,000-7,999	.084	.055	.066	.062	.050	.050
8,000-9,999	.107	.080	.095	.090	.081	.086
10,000-11,999	.106	.101	.133	.110	.105	.109
12,000-14,999	.113	.112	.120	.123	.124	.128
15,000-24,999	.196	.334	.290	.342	.396	.399
25,000-over	.066	.109	.079	.082	.096	.085
Median Household Income	9,840	13,490	11,790	13,150	14,780	14,600

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. *Household Income in 1969 for States, SMSA's, Cities and Counties: 1970*, Washington, D.C.: Government Printing Office, 1973, p. 39, and inflated to 1975 dollars. Income distributions for construction worker, operation worker, and service worker households are from Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that "other newcomers" are operation employees and that new service worker households have the same income distribution as long-time residents. The income data on Colstrip and Forsyth combined closely follow the data for currently affected communities in the West. Colstrip residents tend to have higher incomes than Forsyth residents, largely because the former are nearly all employed by Western Energy Company, whereas Forsyth has a mix of employers.

growth[1] (Table 10-31, Figure 10-10). Since Montana has no sales taxes, the economic benefits to these market centers will be primarily indirect, coming in the form of increased employment and new businesses.

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[1] University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, p. 69; Johnson, Maxine C., and Randle V. White. *Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion.* Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 56; Polzin, Paul E. *Water Use and Coal Development in Eastern Montana*. Bozeman, Mont.: University of Montana, Joint Water Resources Research Center, 1974.

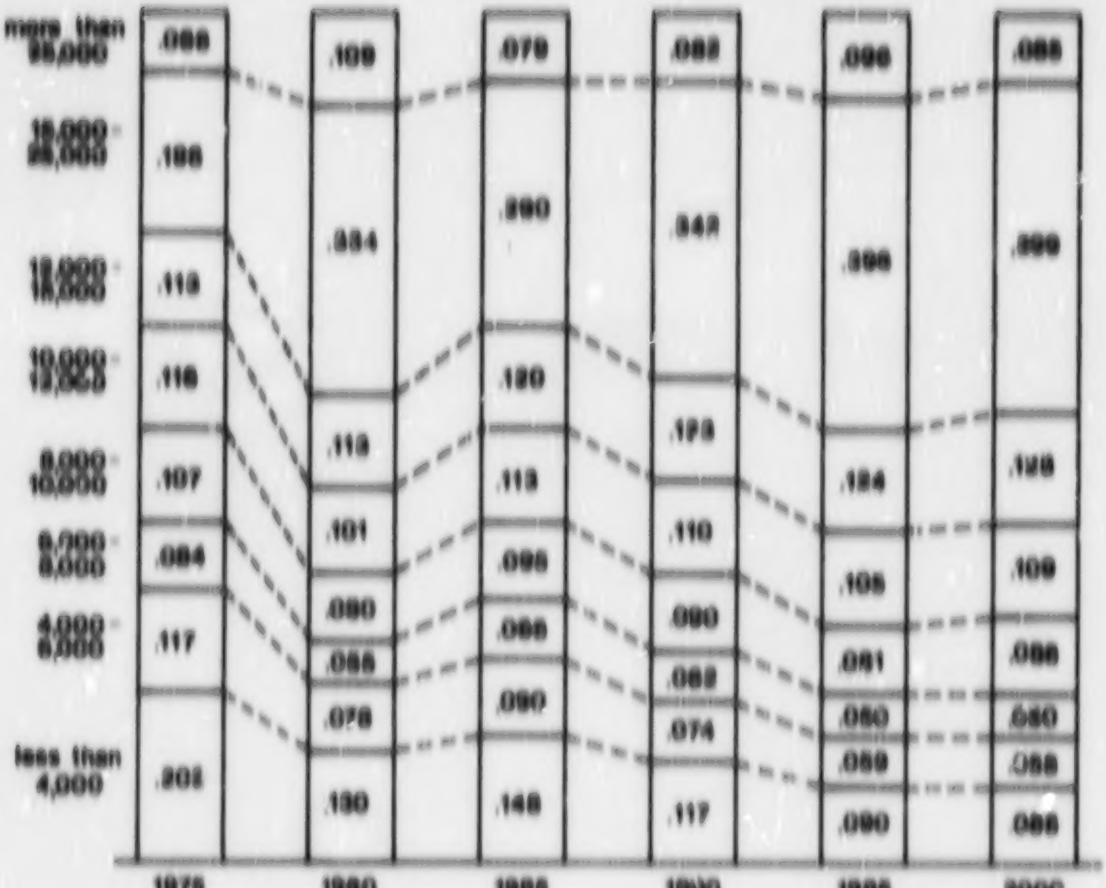

FIGURE 10-9: PROJECTED INCOME DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000
(in 1975 dollars)

TABLE 10-31: PROJECTED POPULATION FOR BILLINGS AREA AND MILES CITY, 1975-2000

Year	Billings	Miles City
1975	75,000	9,200
1980	78,400	9,900
1985	82,000	10,700
1990	86,400	12,200
1995	89,800	13,800
2000	92,800	15,000

Rosebud County finances have been studied extensively,[1] and an analysis specific to this scenario follows in the section on fiscal impacts. The Forsyth water and sewage treatment facilities are currently used to capacity (only primary sewage treatment is available), and an expansion of the system is being studied.[2] As is common for small communities, the expenditure for such facilities is the largest single category of capital requirements (Table 10-32). The major period of expenditure need in Forsyth occurs after 1985, and especially in the early 1990's. Ashland, which currently has no water system, will require about $8 million to meet demands in the 1988-1993 period. However, temporary facilities might be used at some savings.

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[1] U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. *Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties*. Denver, Colo.: Northern Great Plains Resources Program, 1974; Johnson, Maxine C., and Randle V. White. *Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

[2] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII*. Denver, Colo.: Mountain Plains Federal Regional Council, 1975; U.S., Department of Agriculture, Committee for Rural Development. *1975 Situation Statement: Rosebud-Treasure Counties*. Forsyth, Mont.: Department of Agriculture, 1975, p. 64.

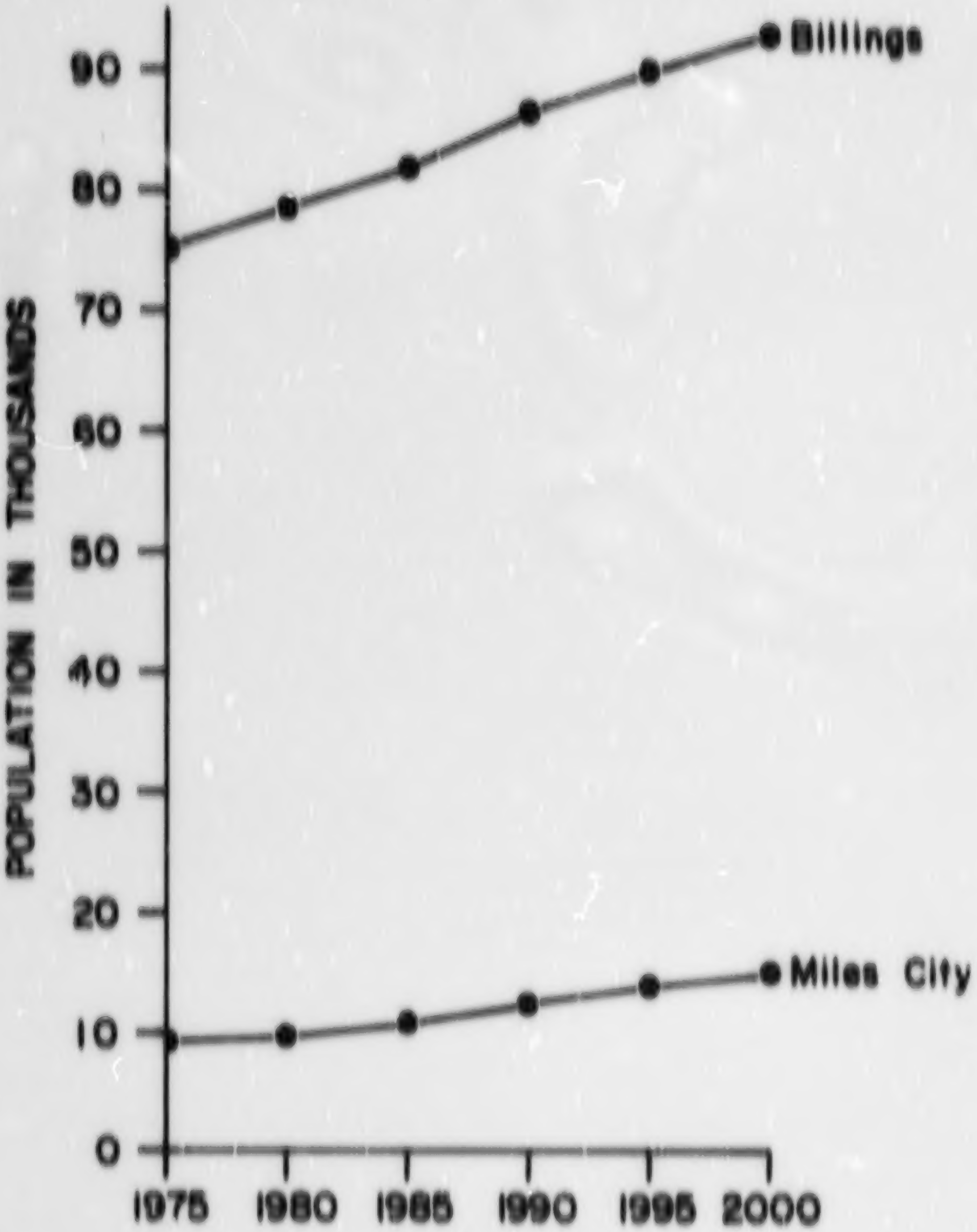

FIGURE 10-10: POPULATION ESTIMATES FOR BILLINGS AND MILES CITY, 1975-2000.

TABLE 10-32: PROJECTED NEW CAPITAL EXPENDITURES REQUIRED IN FORSYTH AND ASHLAND, 1975-2000
(in thousands of 1975 dollars)

	1975-1980	1980-1983	1983-1988	1988-1993	1993-2000
Forsyth					
Water and Sewage[a]	2,320	2,550	3,060	3,300	120
Other[b]	780	860	1,030	1,280	40
Ashland					
Water and Sewage[a]	510	530	6,550[c]	0	0
Other[b]	170	180	2,200[c]	0	0

[a] Water and sewage plant requirements are assumed to be $1,760,000 for each additional 1,000 population, and an additional $591,000 per 1,000 population goes to other physical plant needs. See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars. See also Lindauer, R.L. Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

[b] Other includes parks and recreation (32 percent), hospitals (45 percent), libraries (5 percent), fire protection (5 percent), police protection (3 percent), administration (3 percent), and public works (7 percent). Some of these are not applicable to Forsyth.

[c] 1988 is the expected year of peak population in Ashland.

To meet projected needs, municipal operating expenditures in Forsyth and Ashland must increase five-fold by 2000, the larger increases occurring in the late 1980's and early 1990's (Table 10-33). The provision of necessary services for construction-related populations will be a major problem because property taxes will not provide revenue until the construction is completed. This has been the case in Rosebud County recently.[1]

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[1] U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, p. 63.

TABLE 10-33: PROJECTED OPERATING EXPENDITURES OF FORSYTH AND ASHLAND, 1980-2000 (above 1975 level)[a]

Year	Forsyth	Ashland
1980	458,000	95,000
1983	632,000	131,000
1988	841,000	577,000
1993	1,100,000	530,000
1995	948,000	426,000
2000	1,109,000	522,000
1974 Budget	214,353	NA[b]

[a] Based on a figure of $120 per capita (1975 dollars) broken down as follows: streets and roads (25 percent), health and hospitals (14 percent), police (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), administration (10 percent), sanitation and sewage (10 percent), and other (12 percent). See THK Associates, Inc. *Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study*. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars. These figures will be high estimates for Forsyth because some of these services are provided by county funds.

[b] Not known.

The large revenue benefits from energy development discussed in other studies[1] have only begun to be felt in the towns; they may only partially compensate local municipalities which are forced to absorb large population increases but do not include the energy facilities within their area of taxation. This is likely to be the case for Forsyth, Ashland, and other Rosebud County towns, where newcomers employed in energy development must live.[1] What little land ranchers and other landowners make available for housing will continue to escalate in price, and general inflation for goods and services will be felt. These problems will be worse during intensive construction periods, when greater demands will be placed on local markets.[2]

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[1] Johnson, Maxine C., and Randle V. White. *Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

B. Fiscal

In this section, the tax rates currently in effect in Rosebud County are applied to project incremental revenues likely to arise from energy development. Some taxes, such as severance taxes, apply directly to the energy developments; others, such as personal income taxes, derive indirectly. Some taxes are local, some are state, and some are collected by the state for local distribution.

1. Coal Mines License Tax[3]

This excise tax will probably capture more revenue from energy development than any other tax. The rate will depend on heat content and contract price, but will generally be 30 percent of sales price at the mine.[4] The Resource Indemnity Trust Tax is also based on the value of minerals extracted, in this case at a 0.5-percent rate.[5] Receipts are placed in a trust which will

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[1] If Colstrip remains a company town, then the company could directly provide many facilities from internal funds, without having to go through the tax system. See Section 10.4.B below.

[2] A description of recent experience in the area is found in the University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974.

[3] Montana Revised Codes Annotated, Title 84, Chapter 13 (Cumulative Supplement 1976); Johnson, Maxine C., and Randle V. White. *Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion*. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 43-46.

[4] For heat content greater than 7,000 Btu's/pound (British thermal unit's per pound) and prices greater than $1.40 per ton.

[5] Montana Revised Codes Annotated, Title 84, Chapter 70 (Cumulative Supplement 1976).

TABLE 10-34: SEVERANCE TAX REVENUES FROM COLSTRIP SCENARIO ENERGY DEVELOPMENT (millions of 1975 dollars)

Year	Gross Receipts	Tax Revenues
1978	0	0
1980	0	0
1983	80	24.4
1985	171	52.2
1988	239	72.9
1990	292	89.1
1995	438	133.6
2000	652	198.9

[a] The Coal Mines License Tax accounts for 98.4 percent of the tax revenues in the table, at 30 percent of the mine revenues. The remainder is the Resource Indemnity Trust Tax, at 0.5 percent of mine revenues.

accumulate to $100 million with certain restrictions; this scenario simply credits the funds to the state legislature's discretion.

Projected prices for Western coal indicate a rise from $9.52 per ton in 1983 to $13.94 by 2001 (all figures in 1975 currency).[1] The Colstrip scenario calls for new coal production to reach 47 million tons per year by 2000. Multiplying these quantities together and then by 30.5 percent, annual mine and tax revenues are projected (Table 10-34).

2. Property Taxes

Several forms of property are taxed by a host of governmental units. This analysis concentrates on the energy facilities, associated municipal construction, and "gross proceeds" of mines. It is assumed that energy facilities in the scenario will be taxed during construction in proportion to the resources invested as of each date. The actual value of facilities subject to property tax would thus grow continuously (Table 10-35). It can be seen in the table that the energy developments, rather than the resulting residential and commercial growth, will dominate the tax assessment rolls.

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[1] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics. Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

TABLE 10-35: PROJECTED PROPERTY VALUATION IN ROSEBUD COUNTY (millions of 1975 dollars)

Year	Facilities	Minerals	Residential and Commercial[a]
1978	55	0	4
1980	276	0	11
1983	998	80	23
1985	1,135	171	15
1988	1,831	239	54
1990	2,051	292	31
1995	3,605	438	79
2000	4,862	642	96

[a] Based on $3,800 per capita and population growth in Rosebud County. See Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: University of Montana, Joint Water Resources Research Center, 1974, p. 142.

Taxable values are derived from these actual values by a series of statutorily defined ratios. Most property receives a multiplier of .12, so that the recent mill levy of 94.42 is equivalent to a rate of 1.133 percent of full market value.[1] Applying the tax rates to the taxable values, and using the current formulas for apportionment, likely property tax receipts are summarized in Table 10-36.

These revenues far exceed previous annual receipts in Rosebud County. At the current time (after some energy-related development has already been felt), the county's total of non-utility property has a taxable value of $15.3 million. By contrast, energy facilities will grow to a taxable value of $584 million by 2000, and gross proceeds will reach $117 million. Clearly, these facilities will become the mainstay of local public finances, especially for the school district which depends

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[1] Pollution control equipment has a multiplier of .028, and gross proceeds from strip mining has a multiplier of 18. We do not make separate provision for control equipment in these estimates, however. See Johnson, Maxine C., and Randle V. White, Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

TABLE 10-36: PROJECTED PROPERTY TAX RECEIPTS IN ROSEBUD COUNTY
(millions of 1975 dollars)

	1978	1980	1983	1985	1988	1990	1995	2000
State	0	.2	.8	.9	1.5	1.7	2.9	3.9
County General Purposes	.2	.8	3.3	4.1	6.5	7.4	12.5	16.6
County for Schools	.3	1.9	6.3	7.9	12.6	14.4	24.3	32.3
School District 19	.1	.7	2.5	3.1	4.9	5.6	9.5	12.6
Total Levy	.6	3.6	12.9	16.0	25.5	29.1	49.2	65.4

almost entirely on property taxes. A comparison with Table 10-29 shows that the school districts in Rosebud County can enjoy substantial surpluses if current tax rates are maintained.

The valuation of facilities will probably take on political overtones, considering its crucial role in determining local budgets. The tax assessment process, conducted at the state level, may enjoy some insulation from local political pressures, but these facilities are so capital-intensive as to have a noticeable impact even on the state's tax rolls.

Also, there is a distinct possibility that rates may be reduced, especially those of the property tax and coal mines severance tax. Otherwise (if no major spending programs were introduced), large surpluses would build up in state and county treasuries. Moreover, the 30-percent rate of the license tax far exceeds rates in neighboring states (about 6 percent in North Dakota and 3.5 percent in Wyoming). Thus, this high rate might eventually cause a loss of some development to other states.

3. State Income Tax[1]

The state income tax in Montana is a graduated tax and therefore depends on the income distribution (Table 10-30; Figure 10-9). Including $3,600 in exemptions and deductions for a family of four, the average tax collected per household will be in the range of 6.5-6.6 percent of household income. Taking into account the income distribution in Table 10-30, the total new income tax revenue is shown in Table 10-37.

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[1] See Montana Revised Codes Annotated, Title 84, Chapter 49 (1947).

TABLE 10-37: NEW STATE INCOME TAX RECEIPTS FROM ENERGY DEVELOPMENT
(millions of 1975 dollars)

Year	New Households in Rosebud County	Total New Personal Income	New Tax Receipts[a]
1978	425	5.7	.4
1980	1,330	16.6	1.1
1983	1,955	23	1.5
1985	1,305	15.4	1
1988	5,460	71.8	4.7
1990	3,090	40.6	2.6
1995	7,680	113.5	7.4
2000	9,660	141	9.2

[a] At 6.5 percent of new personal income.

4. Distribution

The state receives all funds generated by electrical producers' and income taxes, and a portion of the mill levy, as detailed previously (Table 10-36). The county government will receive new funds from the coal tax and the mill levy. All new funds for schools will come from mill levies (by the county and by the districts). Further, the Coal Mines License Tax and the Resource Indemnity Trust Tax are distributed as follows beginning in 1979: 41 percent goes to the state general fund; 34.5 percent goes to local impact and education trust funds (of which 3/7 may be disbursed in grants); 21.1 percent goes to state-earmarked purposes (public schools equalization receives 46.5 percent of that portion, park acquisition receives 23.2 percent, energy research receives 18.6 percent, and resource development bonds support receives 11.6 percent); and 3.4 percent goes to the originating county.[1] The distribution of new revenues from all taxes is summarized in Table 10-38.

The property valuation data presented in Table 10-35 showed that less than 2 percent of new *ad valorem* revenues will come from residential and commercial development. Since the energy facilities will be located in unincorporated areas, municipalities will be excluded from the larger part of new property taxes. Combined with the fact that there is no sales tax in Montana, this means that towns such as Forsyth must depend to a great extent on allocations from higher levels of government.

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[1] These figures differ from language in RCM 84-1309.1 because the License Tax and Resource Indemnity Trust Tax have been combined for ease of calculation.

TABLE 10-38: DISTRIBUTION OF NEW TAX REVENUES FROM COLSTRIP SCENARIO DEVELOPMENT
(millions of 1975 dollars)

Year	State General Purpose	State Earmarked Funds	State Grants to Local	County General Purposes	Schools (county and district)
1978	.4	0	0	.2	.4
1980	1.3	0	0	1	2.6
1981	14.3	5.1	3.5	4.1	8.8
1985	31.1	11	7.7	5.9	11
1988	43.9	15.4	10.8	9	17.9
1990	48.6	18.8	13.2	10.4	21
1995	72.9	28.7	19.8	17	33.8
2000	103.5	42	29.4	23.4	44.9

But if all the state impact aid funds are channeled back to their county of origin, then all local needs can be met, with surpluses, after 1981. In the first few years, the fiscal balance will be as shown in Table 10-39.

10.4.7 Social and Cultural Impacts

A distinctive aspect of the Rosebud County area is the continued opposition of many area ranchers to strip mining and other energy development. The arguments are largely economic, since the land and water supplies are crucial to ranching operations, but also include aesthetics (focusing on transmission lines) and combinations of the two (including air pollution effects on visibility and on vegetation).[1]

Newcomers to the Rosebud County area have not been uniformly impressed with living conditions in the area. Land for housing subdivisions is not available, even in small lots, and mobile

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[1] "Colstrip Testimony," *The Plains Truth*, Vol. 5 (February-March 1976), pp. 11-16; see also Montana, Department of Natural Resources and Conservation, Energy Planning Division. *Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities.* Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, Vol. 3-B, pp. 789-825; University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming.* Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 27-35.

TABLE 10-39: CONSOLIDATED FISCAL BALANCE, TOWN OF FORSYTH AND ROSEBUD COUNTY, 1976-1985
(millions of 1975 dollars)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
New Expenditures										
Capital	.05	.11	.67	.85	.80	1.59	1.22	.09	0	.36
Operating	0	.01	.04	.09	.13	.21	.37	.37	.19	.21
New Revenues										
State Aid	0[a]	0	0	0	0	0	0	2.62	3.61	7.73
County	0	0	.16	.44	.83	1.57	2.33	4.09	4.46	5.83
Surplus (Deficit)	(.05)	(.12)	(.55)	(.50)	(.10)	(.23)	.74	7.36	7.88	12.99

[a] The zeros indicate that no such revenues are generated in the county (in our scenario) until 1983. Aid may still be provided by the state with funds generated in other areas. See Section 10.4.E.

home living is the primary alternative. Even in the company-owned town of Colstrip, few families actually own their homes.[1] More unsettling to many families is the separation within Colstrip between construction workers, non-administrative operation workers, and administrators and supervisors, and there is no evidence that this will be eliminated in the future. As a result, a number of workers, especially those with families, have chosen to live in Forsyth.[2] This can be expected to continue.

The major social impacts on long-time residents will be on the ranchers, who perceive their way of life and values threatened by coal development. To newcomers, the lack of land to purchase will force most to live in mobile homes, and those who live in Colstrip will be aware of the housing segregation. For all, local inflation will be a problem when limited competition allows rising prices to take advantage of high incomes.

The quality of life in Rosebud County varies with residential location. Dissatisfaction with medical services, housing availability, and streets and roads is common in both Colstrip and Forsyth. Residents of Colstrip have been quite dissatisfied with entertainment and shopping facilities, resulting in an overall characterization of the town as "isolated" and "dull". In Forsyth, these services are more readily available, and dissatisfactions are more regularly expressed regarding housing quality. People recently living in Forsyth tend to have positive descriptions about the town, characterizing it as "friendly" and "happy". Forsyth's established town atmosphere appears to be much preferred over other locations in Rosebud County.[3]

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[1] For descriptions of Colstrip, see Myhra, David, "Colstrip, Montana--the Modern Company Town," Coal Age, Vol. 80 (May 1975), pp. 54-57; Schmechel, W.P. "Developments at Western Energy Company's Rosebud Mine," in Clark, W.F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 1. Billings, Mont.: Eastern Montana College, Montana Academy of Sciences, 1975, pp. 60-66.

[2] University of Montana, Institute for Social Science Research, A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 16-18, 43-45.

[3] Mountain West Research, Construction Worker Profile, Community Report: Forsyth and Colstrip, Montana. Washington D.C.: Old West Regional Commission, 1976, pp. 28-32 and 56-61.

Medical care will continue to be a pressing need in the county, as in most of non-metropolitan America. At least 16 more doctors will be needed by 2000 just to maintain the current average of one doctor per 1,500 people. Twice that number would be needed to meet national averages. As elsewhere in the West and in rural areas, attracting doctors will be difficult if not impossible. A subsidized group practice with guaranteed working hours would be a possible inducement for practicing physicians. New doctors could also be influenced to locate in small towns through loan forgiveness programs.[1]

10.4.8 Political and Governmental Impacts

As noted in the preceding fiscal analysis, the state and the school districts generally will have sufficient revenues to respond to energy-related impacts. However, the net fiscal status of local units of government, will depend largely on administrative and policy decisions made at the state and county levels of government and by the private owners of Colstrip. For example, Forsyth, which will probably be the major recipient of newcomers, must depend on state-level impact aid and county revenues because the energy facilities in this scenario are located in unincorporated areas. Distribution decisions of this nature become even more critical because Montana has no sales tax.

Funding decisions about facilities and services at Colstrip will be up to the discretion of its administrators, as is the case for any company town. Administrators will have wide latitude in the way they provide services or amenities. In addition, workers on energy developments not participated in by the Western Energy Company may not be allowed to live in Colstrip as long as the company owns the town. Colstrip's ultimate incorporation is not scheduled, and even if it should occur early enough for the town to absorb new residents, the usual strains caused by service demands associated with rapid growth would arise. Decisions in both regards will also influence the number of people locating in other communities.

Actions by the Montana Coal Board clearly will be instrumental in determining whether financial problems in communities outside the immediate area of the mines will be handled adequately. If all Montana state impact funds are channeled back to their county of origin, then fiscal demands for the town of Forsyth can be met, with surpluses, after 1981. During 1976-1981, deficits will be experienced, most notably in 1978 ($550,000) and 1979 ($500,000). Besides funneling state revenues back to Forsyth, two additional factors can be brought to bear on the "lead time" problem experienced in the short term. First, according to state law, county commissioners can request prepayment of taxes on a new industrial facility, not to exceed three times the estimated property tax due the year the facility is completed.[1] These advance funds would provide immediate local impact assistance. Second, the state can use severance tax revenues generated in other parts of the state, just as Rosebud's revenues can later be sent to areas beginning their growth in the 1980's. In fact, Montana already has distributed $3.69 million in such revenues to Rosebud and Big Horn Counties (as of mid-1976). This aid is presently helping to reduce financial hardship in Forsyth, Colstrip, and Ashland.[2]

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[1] Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services. R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

Another government impact category where money appears to be one of the principal problems is law enforcement. Funds are needed for manpower and equipment to adequately handle the large projected influx of people, especially during the construction phase of development. At present, the counties are levying all they can (at least all that is politically feasible) to assist in meeting the needs of their localities. Local revenues are being supplemented by revenue sharing grants and other federal sources. Police protection in both Rosebud and Treasure Counties is a consolidated city-county effort and, in each, is administered by the Sheriff's office. Officers have jurisdiction over their entire county, including rural areas, city properties, and unincorporated towns. In the near future, inadequate protection for Colstrip and Ashland may force incorporation of these towns and formation of their own police departments.[3]

The most important political impacts appear to be related to decisions concerning land use in the area. Local governing bodies in Montana are required by law to adopt subdivision regulations which conform to minimum standards, including: a requirement for environmental assessments; analysis of possible social and economic impacts; and dedication of land for open space (parks) or payment of cash in lieu of land.[4] In addition, a 1975 amendment to the Montana Subdivision and Platting Act establishes specific "public interest" criteria which county commissioners must consider and respond to before taking action on a subdivision application, including expressed public opinion and potential social and environmental effects.[1]

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[1] Montana Revised Codes Annotated § 84-41-105 (Cumulative Supplement 1975).

[2] *Old West Regional Commission Bulletin*, Vol. 3 (September 1, 1976), p. 4.

[3] U.S., Department of Agriculture, Committee for Rural Development. *1975 Situation Statement: Rosebud-Treasure Counties.* Forsyth, Mont.: Department of Agriculture, 1975, pp. 83-84.

[4] Montana Revised Codes Annotated §§ 11-3859 through 11-3876 (Cumulative Supplement 1975).

The majority of the people in Rosebud County are very concerned about the balance between social costs of industrial growth and related economic gains, and they want to play a role in the planning and decisionmaking process for further development.[2] Controversy over planning and zoning decisions may become more pronounced as the area population increases. This is particularly significant since Rosebud County's zoning laws and regulations constrain the availability of land for subdivision purposes, forcing most new residents to locate in existing towns. The resultant expansion of the towns to a more urban character will be difficult for some long-time residents to accept.[3] Others will enjoy the greater range of goods and services available. The county, which as already noted receives much of the taxation benefit from energy development, will continue its adaptation to more populated conditions by expanding roads and cooperating with the local communities. These decisions do not always rest well with the landowners, nearly all of whom are ranchers.[4]

10.4.9 Summary of Social, Economic, and Political Impacts

The Colstrip energy development scenario shows an increase in the Rosebud County population of 25,000 people by the year 2000. The largest population increases are expected in Forsyth, which will grow six-fold during the scenario period to 13,500. Mobile homes will be the major housing type throughout the period, reflecting the unavailability of land for home construction. School enrollments will grow slowly until about 1990 when rapid growth will take place. The expenditure requirements for school districts follow the same pattern, suggesting that lead times may be easier to deal with in Rosebud County.

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[1] This amendment should provide a forum for the public in important growth-related decisions; however, it also raises the potential for political conflict.

[2] U.S., Department of Agriculture, Committee for Rural Development. *1975 Situation Statement: Rosebud-Treasure Counties.* Forsyth, Mont.: Department of Agriculture, 1975, p. 59.

[3] *Ibid*, pp. 57-59.

[4] For example, the decision to build a new road between Colstrip and Forsyth was opposed by area ranchers, who reportedly prefer unpaved roads because they "discourage nosey tourists and cattle thieves." See University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, p. 74.

Local area incomes will change alone with the shift in economic activity. Greater reliance on energy sectors will raise median incomes 48 percent by 2000 and even more during construction booms. These incomes will likely induce local inflation, especially in housing. Miles City and Billings will receive a significant amount of the wholesale and retail activity from Rosebud County development.

Population-related government expenditures follow the trend of population growth, with the greatest need occurring in the early 1990's. Of particular importance will be the water and sewage treatment facilities, which will require over $19 million in capital expenditures by 2000. Although the state and the school districts will generally have sufficient funds to respond to impacts, the municipalities are dependent on coal tax funds and actions by the State Coal Board for adequate revenues for local services.

Rancher opposition to coal development in Rosebud County will probably grow as additional grazing land is strip-mined. The company-owned town of Colstrip provides an uncertain governmental problem through potential prohibitions on living within the town while working nearby. Rosebud County's planning capacity and regulatory ability appear able to constrain the type of unplanned sprawl occurring in some areas in the West.

10.5 ECOLOGICAL IMPACTS

10.5.1 Introduction

The area considered for ecological impacts in the Colstrip scenario extends from the Bighorn Mountains in the southwest, eastward to the Tongue River, and north to the Yellowstone River. Most of the landscape consists of rolling hills broken by more rugged uplands and dissected by several tributaries to the Yellowstone. Elevations range from 2,700 feet at Forsyth to 5,200 feet in the Little Wolf Mountains. The climate is semiarid with extreme annual variations in temperature and occasional violent storms, which together with soil moisture and topography largely determine the abundance and distribution of the biota.[1]

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[1] Packer, Paul E. *Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains*. General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

TABLE 10-40: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, COLSTRIP SCENARIO

Community	Characteristic Plants	Characteristic Animals
Sagebrush Grassland	Green needlegrass Needle-and-thread grass Western wheatgrass Blue grama Big sage Silver sage	Pronghorn antelope Whitetailed jackrabbit Badger Western meadowlark Sage grouse Short-horned lizard
Pine Woodland	Ponderosa pine Rocky mountain juniper Bluebunch wheatgrass Sideoats grama Snowberry Goldenrod	Mule deer Porcupine Bobcat Ground squirrel species Great horned owl Red-shafted flicker Turkey Sharptail grouse
Streamsides	Plains cottonwood Green ash Willow Wild currant Bluegrass Foxtail Dock	Whitetail deer Raccoon Little brown bat Red fox Shorebirds (e.g., killdeer) Yellowthroat Ringneck pheasant Leopard frog

Agricultural practices, particularly livestock grazing and sagebrush eradication programs, are important influences on the ecosystem.

10.5.2 Existing Biological Conditions

The terrestrial ecosystem is characterized by two major biological communities: ponderosa pine and juniper woodlands, and the more gently rolling sagebrush grasslands of lower elevations. In addition to these, floodplains and streambanks support a distinctive riparian vegetation. Table 10-40 lists species characteristic of these community types. Although vertebrate wildlife range across all three of these vegetational types, unifying them into a single ecosystem, many species have seasonal preferences, moving in response to the availability of shelter and forage in winter and succulent vegetation in summer.[1] Rare and endangered species include the perigrene falcon, and bald eagle; the black-footed ferret may also be present.

The diversity of vegetation is related to small-scale topographic variabilities, such as rock outcrops where fissures hold pockets of soil and water for trees. The mixture of vegetation in turn supports a variety of wildlife. The least abundant riparian habitat is probably the most critical to the maintenance of overall ecosystem diversity, as this type is used (at least seasonally) by most of the area's vertebrate species. Its extent has been reduced by irrigated agriculture, especially in the large floodplains of the Yellowstone, Bighorn, and Tongue Rivers.

Rivers support a varied and diverse aquatic fauna and supply important breeding and migration habitat for waterfowl. Fish populations are generally dominated by non-game species such as bullheads, goldeye, carp, suckers, chubs, minnows, and dace. Game fishes in the area include sauger and channel catfish; trout and bass have been introduced. Three native game species of particular importance in the Yellowstone and Tongue River are the paddlefish, shovelnose sturgeon, and pallid sturgeon, which enter the rivers in the spring to spawn. A total of 49 species of fish have been recorded in the Yellowstone in Montana.[2]

The Bighorn Mountains are covered with a variety of coniferous forests, zoned by altitude and topography. Alpine meadows are scattered over the highest elevations. The animal life of the Bighorns is accordingly diverse; game animals include elk, mule deer, black bear, mountain lion, bighorn sheep, antelope, white-tailed deer, and moose. Most of the big game animals are limited by winter range. Several uncommon species requiring special management practices include the wolverine, pine marten, and spotted bat.[1]

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[1] For example, mule deer and antelope tend to use all three types of vegetation, although exhibiting a preference for woodland and sagebrush respectively. The coyote, a major predator, and the deer mouse, an important prey species, are also found in all types of habitats.

[2] Peterman, Larry G., and Michael H. Haddix. "Preliminary Fishery Investigations on the Lower Yellowstone River," in Clark, Wilson F., ed. *Proceedings of the Fort Union Coal Field Symposium* Vol. 3: *Aquatic Ecosystems Section*. Billings, Mont.: Eastern Montana College, 1975, p. 99.

10.5.3 Major Factors Producing Impacts

During the 1975-1980 period, construction will start on the mine-mouth power plant scheduled to come on-line in 1985. The population of Rosebud County will increase by 3,000 (35 percent) most of which will locate in Colstrip and Forsyth.

During the 1980-1990 period, the power plant and accompanying water and transmission lines will be completed, destroying or preempting approximately 4,770 acres of primarily sagebrush-grassland and pine woodland. The Lurgi gasification plant east of Colstrip (and its water and gas lines) will consume 1,790 acres of sagebrush, woodland, and pure grassland. By 1990 the power plant and Lurgi gasification plant will withdraw about 68 cubic feet per second (cfs) from the Yellowstone River which is 1.3 percent of the annual minimum flow. The area population will increase 46 percent, bringing 5,500 more people into the county.

During the 1990-2000 period, the Synthane plant at Colstrip and the Synthoil plant in the Sarpy Creek valley will be constructed and begin operation. With associated facilities these installations will occupy about 7,600 acres of former sagebrush-grassland. Water withdrawals will increase to about 109 cfs for the energy facilities which is 2.1 percent of the annual minimum flow of the Yellowstone River. The Rosebud county population will increase sharply over this decade, rising about 60 percent (the addition of 10,000 people). Two new roads will be built to the mine-plant complex sites, and there will be improved highways connecting the major new population centers.

Strip mining will commence in 1985, and a new mine will be added every 5 years. However, the impacts of habitat removal due to mining will not be fully realized until mining has terminated in all four localities. By that time (approximately 2030) a total of about 17,200 acres of sagebrush grassland and 12,100 acres of pine forest or woodland will have been altered and replaced by planted vegetation.

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[1] In addition, the flammulated owl, American osprey, prairie falcon, grayling, greater sandhill crane, and gyrfalcon have also been described as requiring special management by the Fish and Wildlife Service.

10.5.4 Impacts

A. Impacts to 1980

Vegetation loss during this 5-year period is limited to the area of the power plant site, which presently produces forage equivalent to requirements of 40-60 cows with calves.[1] For purposes of comparison, a 1974 Census of Agriculture Preliminary Report for Rosebud County indicates a total inventory of 94,500 cattle and calves.

At the power plant site, direct habitat removal affects most small vertebrate species locally and is not expected to reduce regional populations. However, the site area is a wintering area for mule deer and antelope, and the disturbance from construction activity may cause big game species to disperse into adjacent areas. Sharptail and sage grouse courtship and brood-rearing activities could be disturbed or displaced as far as 2 miles from the site.

Increases in both legal and illegal hunting are typically associated with large construction projects in the West. Poaching will probably center near Colstrip and the construction site, especially since both mule deer and antelope now concentrate there in winter.[2] Private landowners have already begun to close their lands to hunters and other outdoor recreationists; with the first construction peak, land closure will probably become common. While this action may reduce poaching, it will also focus legitimate big hunting pressure on the nearby Custer and Bighorn National Forests, where hunter success may decline.

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[1] This estimate is derived from the carrying capacity of the different vegetation types in acres per Animal Unit Month (AUM). An AUM is a measure of forage production, and represents the amount of forage required to sustain a cow with calf, or five sheep, for a month. Because food habits differ, the unit cannot generally be applied to wildlife. Since the unit has no time dimension, its interpretation in terms of total numbers of livestock depends on whether the range is used seasonally or all year. Carrying capacities used were: 3.5-7.0 acres/AUM in sagebrush grassland; 3.5-4.0 acres/AUM in pine woodland; and 5.5 acres/AUM in other grassland types (Payne, G.F. *Vegetative Rangeland Types in Montana*. Bulletin 671. Bozeman, Mont.: Montana State University, Montana Agricultural Experiment Station, 1973.)

[2] Unlike legitimate hunting, poaching can reduce the breeding stock by taking females and young, which can affect the ability of the population to replace harvested individuals by reproduction. As populations decline, the number of individuals which may be safely harvested by legal hunters is reduced, and legal hunts may be curtailed or even discontinued.

B. Impacts to 1990

During the second scenario decade, construction of the Lurgi gasification plant will remove additional pine woodland and sagebrush-grassland habitat. The total forage value of the lands affected is roughly equivalent to the yearly needs of about 60-80 cows with calves. Ecological impacts of this habitat loss will be similar to those around the Colstrip power plant site. However, the Lurgi plant does not occupy portions of known key wildlife ranges.

This time period will also see major improvements in vehicular access throughout the scenario area. Highway rights-of-way will generally follow the major stream courses in the area and will constitute a major adverse influence on these restricted habitat zones. By 1990, the volume of traffic along large portions of Armells and Rosebud Creeks and the Tongue River will have increased several-fold. Habitat removal will affect a variety of small birds, mammals, and amphibians, among them the sharptail grouse and ring-necked pheasant. Whitetail deer, largely restricted to valley bottoms, are likely to decline. In particular, the highway following the Tongue River would bisect two mule deer winter concentration areas and an antelope concentration area, increasing road kills and resulting in a slight reduction of the deer and antelope populations.

The growth in areawide human populations, especially at Colstrip and Forsyth, will also contribute to illegal shooting of non-game animals, off-road vehicle (ORV) use, and habitat fragmentation from subdivision and strip development. Birds of prey, such as Swainson's hawk and the golden eagle, which frequent roadsides and perch on power or telephone poles, are most vulnerable to shooting. Varmint hunting can indirectly affect the probability of the survival of black-footed ferrets in the area (if they are present), especially if prairie dog populations are reduced.[1] Other non-target species, particularly the Northern kit fox and other beneficial small predators, may also show noticeable declines by 1990.

Some local disturbance of big game animals and interference with the breeding and nesting of sharptail and sage grouse may occur. Feral dogs (dogs allowed to run loose and become wild) may threaten local wildlife near population centers. Because the town of Colstrip lies within an area of winter deer and antelope concentrations, there is a potential for harrassment by dogs to develop into a sufficiently important stress to effect a reduction in numbers,[1] beginning as early as 1980, in the absence of additional controls.

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[1] A survey conducted by a consulting firm from 1972 to 1975 in a 10x20-mile rectangle bracketing Colstrip did not detect ferrets. Schwarzkoph, William F., and Raymond R. Austin. "Monitoring Wildlife Parameters Prior to Extensive Strip Mining and Operation of Coal-Fired Steam Generating Plants at Colstrip, Montana," in Clark, Wilson F., ed. *Proceedings of the Fort Union Coal Field Symposium*, Vol. 5: *Terrestrial Ecosystems Section*. Billings, Mont.: Eastern Montana College, 1975, p. 668.

Growing municipalities in the area may discharge increasing amounts of sewage effluent into surface waters, at least until new systems can be built. Although discharge from Forsyth would flow into the Yellowstone, the amount will be negligible, even in comparison to the historical low-flow in the Yellowstone. Dilution will reduce nutrient concentrations well below levels that might affect aquatic production. However, continued use of septic systems around Colstrip could contaminate groundwater and transfer nutrients into Armells Creek. Although the stream is intermittent, nutrient enrichment could cause algal blooms that reduce the quality of the aquatic environment for fish.

C. Impacts to 2000

The construction of the Synthane and Synthoil plants and their associated facilities will take place in the last decade of the scenario. Livestock forage lost by converting grazing land to industrial use will be an amount equivalent to the yearly requirements of 50-90 cows with calves. These facilities will further fragment wildlife habitat around Colstrip and the Sarpy Creek Valley. The greatest impacts on wildlife will probably be associated with the loss of thickets and woodlands along valleys affected by road construction. Poaching will probably continue to be associated with peaks in construction activity. The combined effects of habitat loss, vehicular traffic, and increased legal and illegal hunting will probably result in at least moderate reductions in populations of white-tailed deer and pheasant. A zone of urban influence extending several miles around Colstrip may result in which wildlife will be generally less abundant and diverse, and game species will be uncommon. Although the Synthoil plant on Sarpy Creek will be a more isolated influence, it is sited in an antelope winter concentration area and will probably cause some relocation. However, areawide populations of non-game species with small ranges are not likely to be affected as strongly.

All the scenario facilities emit air pollutants into the atmosphere, the greatest quantities coming from the power plant. Although a variety of pollutants are emitted, including trace elements and hydrocarbons, the potential effects on vegetation may result from sulfur dioxide (SO_2) and fluorine. In the first-year analysis, emissions of fluorine were not calculated. Acute injury normally results from exposures of a few hours to high levels of SO_2. Short-term field fumigation studies have revealed threshold sensitivities of 1.0-1.5 parts per million (ppm) for range grasses,[1] and between 1 and 6 ppm for sagebrush and associated shrubs.[2] SO_2 damage to white and jack pine has been observed in the field with continuous exposure to between 0.13 and 0.5 ppm ambient concentrations;[3] laboratory and field fumigation tests have produced injury in ponderosa pine between 0.4 and 10.0 ppm, depending on the investigator.[4] Crops grown in the Colstrip area are largely alfalfa and winter wheat, both of which are sensitive to SO_2. Acute damage has occurred in wheat at concentrations of 0.20-0.40 ppm[5] and in alfalfa at 0.5 ppm.[6]

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[1] The net impact of such growth-related stresses is not always to reduce the stability of the population but to lower the proportion of the total ("surplus") that can safely be removed by hunting without threatening the balance.

Dispersion modeling indicates that the highest short-term ground-level concentrations experienced, with all facilities on line, will be 0.26 ppm (3-hour average) downwind of the power plant. Under most circumstances, concentrations will be at least an order of magnitude less. This maximum level could damage wheat crops and dispersion conditions producing these high concentrations occur mainly in the winter. Spring brings the most favorable conditions for ventilation.

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[1] Tingey, D.T., R.W. Field, and L. Bard. "Physiological Responses of Vegetation to Coal-Fired Power Plant Emissions," in Lewis, R.A., N.R. Glass, and A.S. Lefohn, eds. The Bioenvironmental Impact of a Coal-Fired Power Plant, 2nd Interim Report, Colstrip, Montana, EPA-600/3-76-013. Corvallis, Oreg.: Corvallis Environmental Research Laboratory, 1976.

[2] Hill, A.C., et al. "Sensitivity of Native Desert Vegetation to SO_2 and to SO_2 and NO_2 Combined." Journal of the Air Pollution Control Association, Vol. 24 (February 1974), pp. 153-57.

[3] Dreisinger, B.R. "Monitoring Atmospheric Sulfur Dioxide and Correlating Its Effects on Crops and Forests in the Sudbury Area," in Conference on the Impact of Air Pollution on Vegetation: Proceedings. Toronto, Canada: Ontario Department of Energy and Resources Management, 1970; Linzon, S.N. "Damage to Eastern White Pine by Sulfur Dioxide, Semi-Mature Tissue Needle Blight, and Ozone." Journal of the Air Pollution Control Association, Vol. 16 (March 1966), pp. 140-44.

[4] Hill, et al. "Sensitivity of Native Desert Vegetation."

[5] Guderian, R., and H. Van Haut. "Detection of SO_2 Effects Upon Plants." Staub-Reinhaltung der Luft, Vol. 30 (1970), pp. 22-35.

[6] Tingey, D.T., et al. "Vegetation Injury from Interaction of Nitrogen Dioxide and Sulfur Dioxide." Phytopathology, Vol. 61 (December 1971), pp. 1506-11.

Chronic damage typically occurs when SO_2 levels are much lower than those required to induce direct injury. Chronic SO_2 pollution damage of alfalfa and wheat may be possible downwind of the power plant. Judging from the relatively higher tolerances of native plants to acute SO_2, these species may be less likely to develop chronic injury symptoms. However, in the absence of appropriate data, the possibility cannot be ruled out.

Beginning with the opening of the power plant in 1985, the scenario's water demands will be capable of reducing low-flow in the summer months in the Yellowstone River during dry years to a point where some short-term ecological response may become noticeable. The magnitude of such flow reductions would be greater downstream of the scenario area near the Yellowstone-Missouri confluence than in the withdrawal area. Between Miles City and Sidney, large irrigation withdrawals currently reduce summer low-flows by an amount equivalent to roughly 50 percent of the low-flow of record. Outside the growing season, including the spring runoff period critical to migratory spawners such as the paddlefish and sturgeon, flow near Sidney is appreciably greater than at Miles City. For this reason, even though the impact on summer low-flow could be significant in the lower Yellowstone, no interference with the reproductive patterns of either spring or fall spawning fishes are expected to result from the Colstrip scenario alone.

Water removal by the scenario developments for energy facilities peaks at 79,000 acre-feet per year by the end of the scenario time frame. The impact of this use depends on the ecosystem dynamics of the Yellowstone River. Key ecosystem components are presently under intensive study but are not yet sufficiently well known to permit establishment of in-stream flow requirements.[1] Consequently, it is not possible to predict the magnitudes of the ecological consequences of reduced summer low-flows. However, possible effects include additional sedimentation to a limited degree during summer, reducing the productive riffle areas crucial to the food supply of most game fishes, and reducing the area of quiet backwaters, island edges, and vegetated banks important for the growth and survival of many juvenile fishes.[1] These impacts would be temporary, and a return to normal flow conditions will permit the ecosystem to restore its balance in subsequent years.[2]

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[1] Performed by the Montana Department of Natural Resources for the Old West Regional Commission, Dr. Kenneth Blackburn, Project Coordinator.

Dewatering of active mines can affect discharge in springs and seeps, with consequent reductions in the base flow of springs. The severity of the resultant ecological consequences will depend on the scale of the impact and cannot be predicted with certainty. However, the following kinds of impacts could occur if discharge were eliminated over a large portion (for example, 25 percent) of the Rosebud Creek Basin throughout the entire time frame:

1. Reduction in diversity and biomass of the Rosebud Creek ecosystem. The stream is not important as a fishery, but loss of ecosystem productivity would affect terrestrial species such as the raccoon, shorebirds, and waterfowl.

2. Reduction in extent and vigor of riparian vegetation dependent on stream underflow. Losses of this type of vegetation, if extensive, would reduce carrying capacity for all species listed as characteristic of this vegetation type, including white-tailed deer, sharptail grouse, pheasant, muskrat, and mink. Sage grouse brood-rearing areas could also be affected.

3. Reduction in density of smaller wildlife dependent on springs and seeps for watering, including mourning dove and several species of rodents. More drought-resistant forms, such as Ord's kangaroo rat and woodrats, may replace the species lost.

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[1] Peterman, Larry G., and Michael H. Haddix. "Preliminary Fishery Investigations on the Lower Yellowstone River," in Clark, Wilson F., ed. *Proceedings of the Fort Union Coal Field Symposium* Vol. 2: *Aquatic Ecosystems Section*. Billings, Mont.: Eastern Montana College, 1975, p. 99.

[2] The Yellowstone is expected to supply water not just for the development of the immediately adjacent coal deposits but for industry as far away as Gillette. Therefore, although the Colstrip scenario in itself is not expected to result in major ecological damage from dewatering, regional water demands could occasion serious stress. The ecological impacts of withdrawals at this scale are discussed in Chapter 12.

Reduction of runoff due to impoundment of mine and plant site drainage, affects 6,400 acre-feet of runoff lost to the Sarpy, Armells, and Rosebud Creek drainages. This will combine with that of reduced groundwater discharge to produce the impacts discussed above.

By the year 2000, all the scenario facilities will accumulate impounded wastewaters on site. All these waste ponds will contain considerable amounts of carbonate and sulfate salts, together with various trace metals and chemical wastes from demineralizing operations. In addition, wastewaters from coal conversion may contain a variety of toxic organic compounds, especially phenols (a number of organic agents known or thought to be carcinogenic), as well as dissolved hydrogen sulfide and ammonia. These materials could pose a threat to wildlife if they were repeatedly consumed or contacted.[1] Impoundments made of reclaimed mine spoils and ash might leach heavy metals in waters or be incorporated into aquatic and terrestrial food chains, depending on concentration and food chain links with the terrestrial ecosystem. Even with these conditions met, the resulting ecological impacts would be local.

An important feature of the Colstrip scenario is the limited availability of public land open to or suitable for camping, hiking, hunting, fishing, and snowmobile and ORV use. The closest public lands are the two National Forests: Custer in Montana and Bighorn in Wyoming.

The greatest potential for damage exists in the Bighorn National Forest. The forest will probably be a regional focus for recreation for increased populations throughout the entire Powder River resource region. Large areas of the forest are closed to vehicular traffic, or otherwise restricted, in the winter months, which will tend to concentrate ORV and snowmobile use on the remaining open areas. Wilderness areas will receive heavy foot and horse traffic in the summer months, unless restrictions are placed on the number of visitor days permitted. Although numerous forest species are tolerant of human activity, some species (including elk, pine marten, and bighorn sheep) avoid areas of heavy human activity. Disturbance of these animals may result in a complex pattern of redistribution which could increase competition with other species. For example, if elk are displaced onto lower elevation in winter, they may compete with deer. Deer usually decline under these circumstances unless the winter range is under-utilized. In addition, subdivision of private lands along the boundaries of the National Forest can fragment deer winter range.

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[1] Wildlife will probably not drink from these impoundments even though conventional fencing would deter few species. The extreme saltiness and probably unpleasant odors will render these waters unpalatable, especially with clean water available nearby in the water reservoirs at each site. Water-fowl may occasionally land on these ponds, especially during migration, but in the absence of aquatic vegetation or animal life would not remain long enough for repeated contact with carcinogens to increase the risk of tumor formation. Thus, the toxic and carcinogenic compounds retained in impoundments will probably not constitute an actual hazard to wildlife.

As fishing increases in the high mountain lakes, the quality of the sport fisheries will decrease, although more intensive stocking programs can help maintain fish populations. However, without careful management of use, relatively fragile vegetation around these lakes may be severely damaged by campers and pack trains, especially above timberline. Smaller wildlife (such as pikas, ground squirrels, and marmots) could also decline in numbers around heavily used areas, especially if dogs are permitted in the high country.

D. Impacts After 2000

The ultimate impact of mining on 17,200 acres of sagebrush-grasslands and 1[illegible],100 acres of pine forest and savanna will depend on the success with which they are reclaimed. Although variable, the overall climate around Colstrip favors reclamation. However, during period of drought, moisture stress will reduce the success of new plantings and alter the species composition of existing stands.[1]

Overburden characteristics vary widely between the coal fields of southeastern Montana. While spoils from the existing mine at Colstrip are not excessively saline, overburden at the nearby Decker mine and in the neighboring Otter Creek coal field contains layers which are salty enough to cause problems with the initial establishment of vegetation. At Decker, it has been shown that salinity of the surface spoil is reduced acceptably after the first 1 or 2 years, especially if irrigated.[2]

Although with proper fertilization and surface treatment spoils can be returned to a productive cover of grasses, it has proven more difficult to reestablish woody vegetation equivalent to the pre-existing biological community. Ponderosa pine, important over almost half the total mine areas, will be particularly difficult to restore, both because it requires a long time to mature and because its need for water is generally greater than that of the grasses.

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[1] Short-term climatic fluctuations in the Colstrip area result in severe droughts lasting 2 years or more, recurring at 1- or 2-decade intervals. Drought cycles of 15-20 years are characteristic of this area, with drier than normal years occurring more frequently than years with above-average precipitation.

[2] Farmer, E.E., et al. Revegetation Research on the Decker Coal Mine in Southeastern Montana, Research Paper INT-162. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

The foregoing factors suggest that reclamation efforts may partially or completely restore grazing values in most years barring problems with excess salts in the soil but will not restore the original native cover.[1] Thus, the original ecosystem of mined areas will probably not be restored, since both topographic and vegetational diversity are critical factors. Therefore, the 19,200 acres mined in the scenario should be considered a long-term loss to wildlife such as antelope, sage grouse, and a large number of songbirds which depend on shrubby cover at some critical point in their life cycle.

The cumulative impacts of the direct removal of land from agricultural production are very small compared with the local agricultural potential of Rosebud County (Table 10-41). The total forage value represented by the full extent of the four strip mines of the Colstrip scenario is equivalent to the amount of vegetation consumed in a year by 460-700 cows with calves.[2] The degree to which this grazing value is restored will depend on climatic patterns, spoil characteristics, and grazing management. However, assuming that mined lands can be restored to only half their original livestock carrying capacity, the total scenario loss of livestock would only be approximately 600-1,200 cows and calves. This total is roughly 1 percent of the 1974 inventory of cows and calves.

Small amounts of cropland in the Armells Creek Valley will be removed by strip mining and community expansion; some agricultural land will also be preempted by the construction of new roads in the Tongue River and Rosebud Creek valleys. While exact acreage figures are not known, the total will be well below 1 percent of Rosebud County's 1974 cropland total of 157,400 acres. Toward the end of the scenario, and after 2000, salinity increases brought on by contamination of groundwater by mine leaching could

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[1] The largely discontinued agricultural practice of repeated summer fallowing has resulted in the loss of some 300,000 acres of cropland in Montana because of the deposition of salts in the surface soil. Salts dissolved from the lower layers are carried upward through evaporation into the surface. A similar problem could arise in irrigated or fallowed spoil material. Mine reclamation experience in this region has not covered a long enough time span for such a phenomenon to be observed.

[2] Between 5,480 and 8,370 Animal Unit Months.

TABLE 10-41: POTENTIAL LIVESTOCK PRODUCTION FOREGONE: COLSTRIP SCENARIO[a]

	Acres Lost	Animal Equivalents	
		Cow/Calves	Sheep
1975-1980	2,400	40- 60	5-10
1980-1990	3,820	50- 80	5-10
1990-2000	3,740	50- 90	10-20
Past-2000[b]	5,000	80-120	25-50
Cumulative Total	14,960	220-350	25-50
1974 Inventory Rosebud County[c]		94,499	15,245[d]
Loss (% of 1974 Inventory)		0.2-0.4	0.2-0.3

[a] Includes rights-of-way.

[b] Represents amount of land unreclaimed at any time, after all mines have been in operation for 5 years.

[c] U.S., Department of Commerce, Bureau of the Census. _1974 Census of Agriculture; Preliminary Report, Rosebud County, Montana._ Washington, D.C.: Government Printing Office, 1976.

[d] Includes lambs.

reduce the extent of irrigated agriculture locally near the mines. However, salinities would have to rise between 10- and 100-fold to enter the range toxic to crops; this is unlikely even in the immediate vicinity of the contamination source.

10.3.5 Summary of Ecological Impacts[1]

Table 10-42 summarizes expected population trends in selected animal species over the scenario period. However, climatic fluctuations characteristic of southeastern Montana can, and probably will, modify these predictions considerably either by imposing ecosystem-wide stress (drought, winter conditions) or especially benign conditions (abundant spring and summer rainfall, easy winters).

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[1] The following discussion does not include the Bighorn Mountains.

TABLE 10-42: PROVISIONAL POPULATION FORECASTS FOR SELECTED MAJOR SPECIES: COLSTRIP SCENARIO

	[illegible]	[illegible]	[illegible]
Game Animals			
Mule Deer	Continuation of present downtrend. Likely start of scenario act. ly.	Aggravation of downtrend through combined influence of poaching and facility siting in wintering area near Colstrip.	Possibly increased downtrend as population growth, further construction, increase in poaching, and additional urban and industrial growth at Colstrip displace wintering deer concentrations.
Whitetail Deer	Continuation of present uptrend. Independent of scenario.	Stabilization and possible downtrend through poaching, habitat loss from road construction.	Definite downtrend due to increased poaching and construction of facility and roads in all major drainage bottoms.
Antelope	Continuation of recent downtrend. Independent of scenario activity.	Aggravation of downtrend due to poaching and facility siting in winter concentration area near Colstrip.	Probable increase in downtrend due to additional facility siting in winter concentration areas, especially around Colstrip, as well as increased poaching.
Sage Grouse	Continuation of recent downtrend. Independent of scenario activity.	Slight local decline around Colstrip.	Definite decline around Colstrip, due to mining activities and urban influence. Effects of noise [illegible] may be locally significant.
Pheasant	Continuation of recent downtrend. Independent.	Decline around Colstrip. Rosebud and Armells Creek drainages from habitat loss.	Continued decline, spreading to Sarpy Creek drainage.
Turkey	Little change due to scenario activity.	Little change due to scenario activity.	Possible slight downtrend if poaching pressure is heavy.
Waterfowl	Little change.	Little change.	Little change.
Rare Species			
National Level			
Peregrine Falcon	Little change.	Possible loss of individuals from illegal shooting.	Increased probability of loss of individuals from shooting.
Bald Eagle	Little change.	Possible loss of individuals from illegal shooting or automobile collisions.	Probable loss of individuals from shooting, collisions.
Black-footed Ferret	Little change, if present.	Little change.	Little change, unless inhabited prairie dog colonies are subjected to heavy shooting pressure.

TABLE 10-42: (Continued)

	[illegible]	[illegible]	[illegible]
Indicators of Ecological Change			
Mining and Reclamation			
Prairie Vole, Cottontail	Little change.	Elimination on mined land, early reclaimed areas. This may recolonize well-[illegible] stands of grasses.	Both species begin returning to old reclaimed areas.
Richardson's Ground Squirrel	Little change.	Elimination on newly mined land. If spoil texture permits burrowing, may come to be a dominant, in/at on newly reclaimed areas.	Increasing importance on reclaimed areas of "middle age," especially if weathering improves suitability of spoil for burrowing. Decline on old reclaimed areas, with dense grass stands.
Dewatering of the Yellowstone River			
Sauger	No change.	Probably no noticeable change.	Possible restriction of distribution between Miles City and the Missouri confluence.
Carp, sucker, buffalo	No change.	Probably no noticeable change.	Possible slight increase in abundance in the overall fish fauna below Miles City.

Noticeable impacts on game animal populations arising from scenario activities will not develop until the first construction peak in the 1980-1990 decade. Recent wildlife population trends of the Colstrip area have been downward since 1971, and these trends have been projected arbitrarily over the remainder of the 1975-1980 period.

The greatest local impact on mule deer populations will arise from the encroachment of mining and residential-urban growth on wintering habitat near Colstrip. In addition, poaching may be expected to have moderate to serious consequences. By the 1990-2000 decade, only scattered groups of deer may continue to winter there. Roads passing directly through wintering areas may also result in increases in road kills, possibly followed by changed distribution patterns. The cumulative impact of all these influences is expected to be a moderate decline in deer numbers throughout the scenario area, especially around Colstrip.

Antelope around Colstrip will be affected by the same stresses as mule deer but to a somewhat greater degree because more wintering habitat is affected. The continued presence of large expanses of superior antelope habitat north of the Yellowstone will tend to reduce the regional significance of this loss. However, by 1995, antelope may have declined to very low levels in Rosebud County.

Of the three major game birds in the Colstrip area, pheasants will suffer most from the loss of habitat and sage grouse least. Loss of springs and seeps and reduced stream flow due to mine dewatering and runoff interception may also eliminate some brood-rearing habitat for these species. However, closure of private lands to hunting may counteract these trends to the extent that while local declines may be observed in the immediate vicinity of the plant sites and Colstrip, overall county populations may remain largely unaffected.

Three species currently listed as threatened by the Fish and Wildlife Service may be found in the Colstrip area. The bald eagle and peregrine falcon are seasonal visitors; both are susceptible to illegal shooting, but the impact of such individual losses on overall population levels is probably outweighed by influences on breeding habitat elsewhere.

Although apparently absent from the immediate Colstrip vicinity, the black-footed ferret has been confirmed in Rosebud County as late as 1972. The main threat to these animals from the scenario developments will probably be through destruction of prairie dog towns inhabited by ferrets. Intensive study in the areas where most of the scenario facilities will be sited has so far failed to discover the animals.

The prairie falcon, recently removed from the Fish and Wildlife Service list, is an uncommon resident which may breed in the scenario area. These birds are also subject to illegal shooting; if they breed in the area, they could, unlike the other two raptor species, decline because of shooting losses.

Several species of mammals and fish can be considered as indicators of ecological change. Reclaimed mine areas may, for a time, take on the character of early successional communities and support a fauna dominated by rodents. Richardson's ground squirrel, which feeds to a large extent on weedy forbs, may be an indicator of the formation of this kind of community, provided that the texture of the soil permits burrowing. Species characteristic of mature vegetation include the prairie vole and cottontail rabbit; the first requires relatively dense stands of grasses, while the second prefers brushy areas. Their absence is an indication of the degree to which the vegetation has been modified from its original structure, and their return will signal at least partial success in restoring wildlife values. Dewatering in the Yellowstone is expected to result in only minor and temporary changes in the ecosystem. Such change as may be observed would probably first be indicated by a restriction in the distribution of the stonecat, a species especially sensitive to flow conditions, below Miles City. The somewhat more pervasive ecological change which might result from cumulative water withdrawals for industry outside the immediate scenario area would be signaled by an increase in the dominance of such generalist fish species as carp, catfish, and suckers.

Table 10-43 ranks the major impacts on the ecosystem into three classes, based on their severity and extent. Class C includes impacts which are expected to be very localized (within a few square miles) and thus will not create measurable changes in the stability of areawide animal populations. Thus, direct habitat removal is included until 1980, as are alterations in groundwater discharge. Water withdrawals from the Yellowstone (for this section) are also placed in Class C because of the infrequency with which they would occasion adverse impacts and because the natural adaptive characteristics of the ecosystem are considered capable of compensating for such infrequent disturbances.

Class B impacts include those that affect animal populations which range over larger areas (the size of National Forests or counties). This class includes game poaching and illegal shooting of non-game species, such as raptors, and growing demands on the recreational resources of the two nearby national forests.

Class A impacts include those which are considered to be the key factors involved in the projected declines of animal populations discussed above. Habitat loss and fragmentation, particularly in limited streamside habitats and winter concentration

TABLE 10-41: SUMMARY OF MAJOR ECOLOGICAL IMPACTS

Impact Category	1975-1980	1980-2000
Class A	Fragmentation of deer and antelope wintering areas by facility, town siting, mining.	Continued fragmentation of sagebrush-grassland habitat. Fragmentation of riparian habitats.
Class B	Illegal shooting	Illegal shooting Increased recreational pressure on national forests
Class C	Grazing losses Loss of irrigated cropland	Grazing losses Loss of irrigated cropland Water withdrawal from Yellowstone Acute SO_2 damage to crops
Uncertain	Contamination of Armells Creek by sewage from septic systems	Contamination of Armells Creek by sewage from septic systems Chronic SO_2 damage to sensitive vegetation Local flow depletions of springs and seeps from mine dewatering Contamination of groundwater from mine spoil leaching

SO_2 = sulfur dioxide

areas, are key aspects of the scenario that cannot be materially reduced. Because critical wildlife habitats are affected, the severity of the impact cannot be much lessened by management of remaining lands, as can be done with livestock grazing. The limitations of geology and climate on reclamation also curtail the potential restoration of wildlife values on mined lands.

10.6 OVERALL SUMMARY OF IMPACTS AT COLSTRIP

The primary benefits of the hypothetical energy developments in the Colstrip area will be the production and shipment of 500 million cubic feet of synthetic natural gas per day, 100,000 barrels per day of synthetic crude oil, and 3,000 megawatts of electricity. However, these benefits clearly will accrue primarily to people outside the area. Local benefits are principally economic and include increased tax revenues for state as well as county and local governments, increased retail and wholesale trade, and secondary economic development. New revenues will provide for expansion of municipal services, such as water distribution and treatment systems, police and fire protection services, and improved health care facilities. Local governments will generally be hard-pressed initially to provide the services for the increased population. Existing school, housing, health, and public safety services will be overwhelmed at the outset by the influx of workers and their families. For example, in Rosebud County a four-fold increase in population by 2000 will result in increases in both the demand for housing and for educational facilities. Revenues produced by the development will be adequate to pay for the education demands, but municipal services in the 1975-1980 time frame will be inadequate for the construction population as revenues do not improve until the operation phase in the mid-1980's.

Many of the negative impacts associated with increased population could be minimized if coal rather than electricity and synthetic oil and gas was exported from the Colstrip area. Construction impacts would be reduced while revenue benefits to the state from producing the resource would continue. However, elimination of the conversion facilities would substantially decrease both capital investment and additions to the property tax base which provide for expanded local public services. Alternative rates of development or scheduling affect the social impacts from construction phases of the energy developments. If the construction phases of the different facilities were coordinated, the minor boom and bust cycles could be avoided. This would be a significant advantage for planning housing and educational facilities.

Air quality impacts from the energy development at Colstrip will be limited to the violation of the federal ambient hydrocarbons (HC) standard. The violation will occur in connection with the Synthoil facility and the increased urban growth at Colstrip. All other federal standards, as well as Environmental Protection Agency's Non-Significant Deterioration increments, will be met. Control of fugitive HC at Colstrip from the Synthoil facility are difficult to achieve short of locating the plant elsewhere.

Water quality impacts may be minimized by achieving FWPCA zero discharge goals. The most significant water quality impact will be associated with municipal water treatment facilities. It is doubtful that Forsyth, the only community in Rosebud County which currently has a wastewater treatment facility, will be able to expand its facility at the rate necessary to match the projected population growth. The other communities rely on septic tanks, which will pose a hazard to groundwater quality. This may ultimately pose a special hazard to the Colstrip residents because they will be relying on groundwater resources for their municipal water needs.

Meeting the water requirements of the energy development will take a small fraction of the average flow of the Yellowstone River, but this may be significant during periods of low flow. Groundwater aquifer systems in the Colstrip area may be depleted as a result of Colstrip's increasing municipal requirements, coal mine dewatering practices, and decreased surface runoff, which will increase the infiltration rate.

Flow reduction in the Yellowstone can be reduced by wet/dry or dry cooling of the power plants at greater economic cost but with savings of up to 75 percent of the water demand for the energy facilities. A minimum of water from the Yellowstone would be used if the coal was shipped out of the region before conversion.

Significant ecological impacts include converting approximately 60,000 acres of vegetation to plants and mines by the year 2000. Even though much of this land will be returned to grassland following reclamation, the change, together with habitat fragmentation, will likely decrease productivity of selected species. Combined with habitat attrition and poaching from the increased population, some species of game will be adversely affected unless positive steps are initiated in protection and game management.

CHAPTER 11

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE BEULAH AREA

11.1 INTRODUCTION

The hypothetical energy development proposed in the Beulah scenario will take place in Mercer, Oliver, and McLean Counties in west-central North Dakota, although most development is centered around Beulah in Mercer County (Figure 11-1). This development consists of five surface coal mines that will produce from 10-20 million tons per year, a 3,000 megawatts-electric minemouth electric generation plant, and four coal gasification plants, each capable of producing 250 million standard cubic feet per day.[1] The location of these facilities is shown in Figure 11-2. Although some of the electricity and gas will be distributed within North Dakota, most of the energy will be shipped to demand centers farther eastward via gas pipelines and electrical transmission lines. Construction of these facilities began in 1975, and all the facilities will be fully operational by 2000. The technologies to be deployed and the timetable for their deployment are presented in Table 11-1.

The three-county area is generally characterized by low unemployment, farming and privately owned lands. Aside from agriculture, the remainder of the laborforce is distributed mostly in the service and trade industries and government services. Manufacturing has been extremely limited. The reliance on agriculture has resulted in a steadily shrinking population (30 percent smaller in 1970 than in 1950).

The topography is primarily gently rolling prairies; the climate is semiarid with extreme seasonal variations in temperature. Much of the past ecological diversity has recently given

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[1] While this hypothetical development may parallel development proposed by Baukol-Noonan, Minnkota Power Cooperative, Knife River Coal Mining, Consolidation Coal, Montana-Dakota Utilities, Coteau Properties, American Natural Gas, Basin Electric Power Cooperative, United Power Association, Falkirk Mining, and others, the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

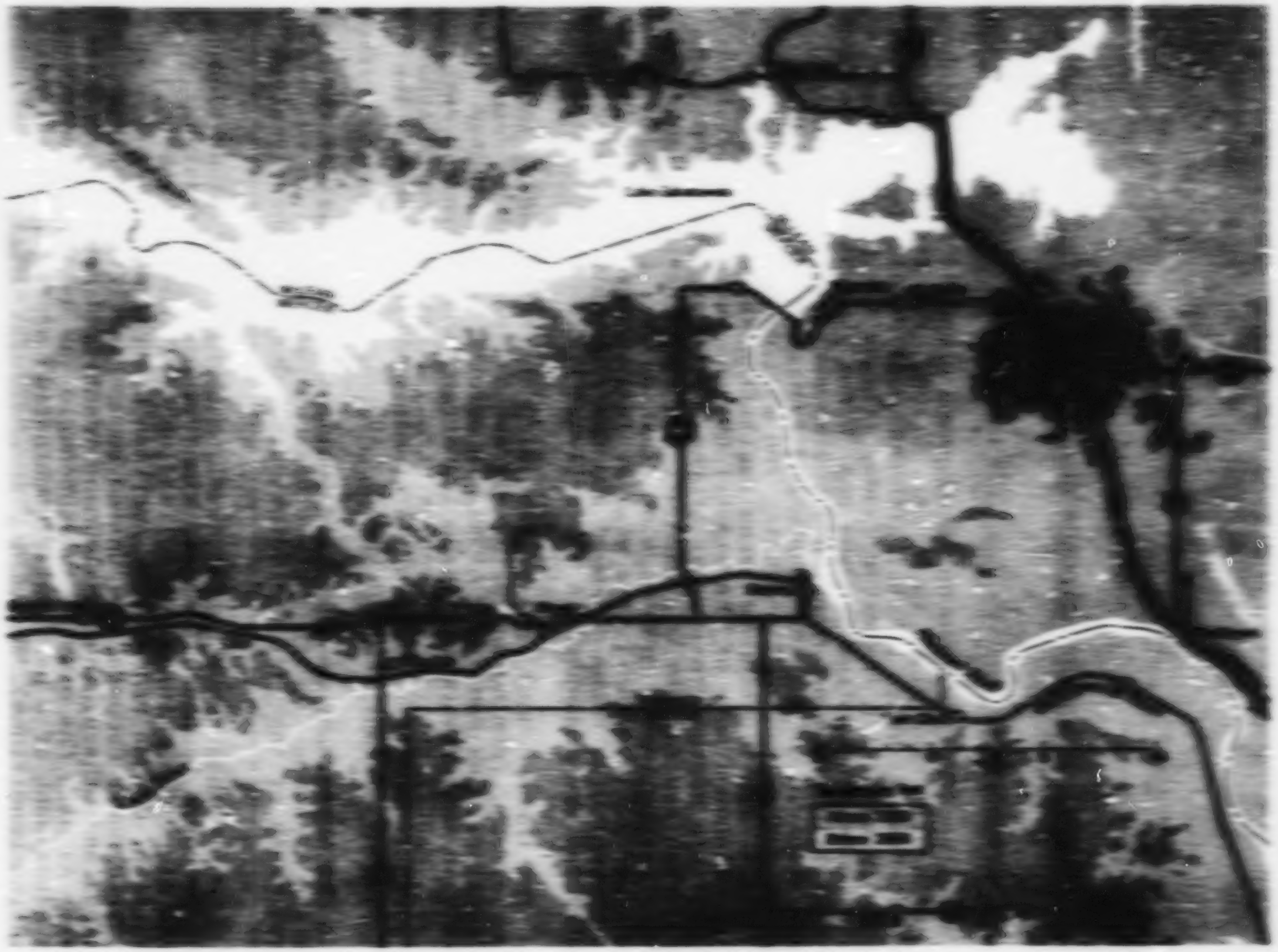

FIGURE 11-7: THE BEULAH SCENARIO AREA

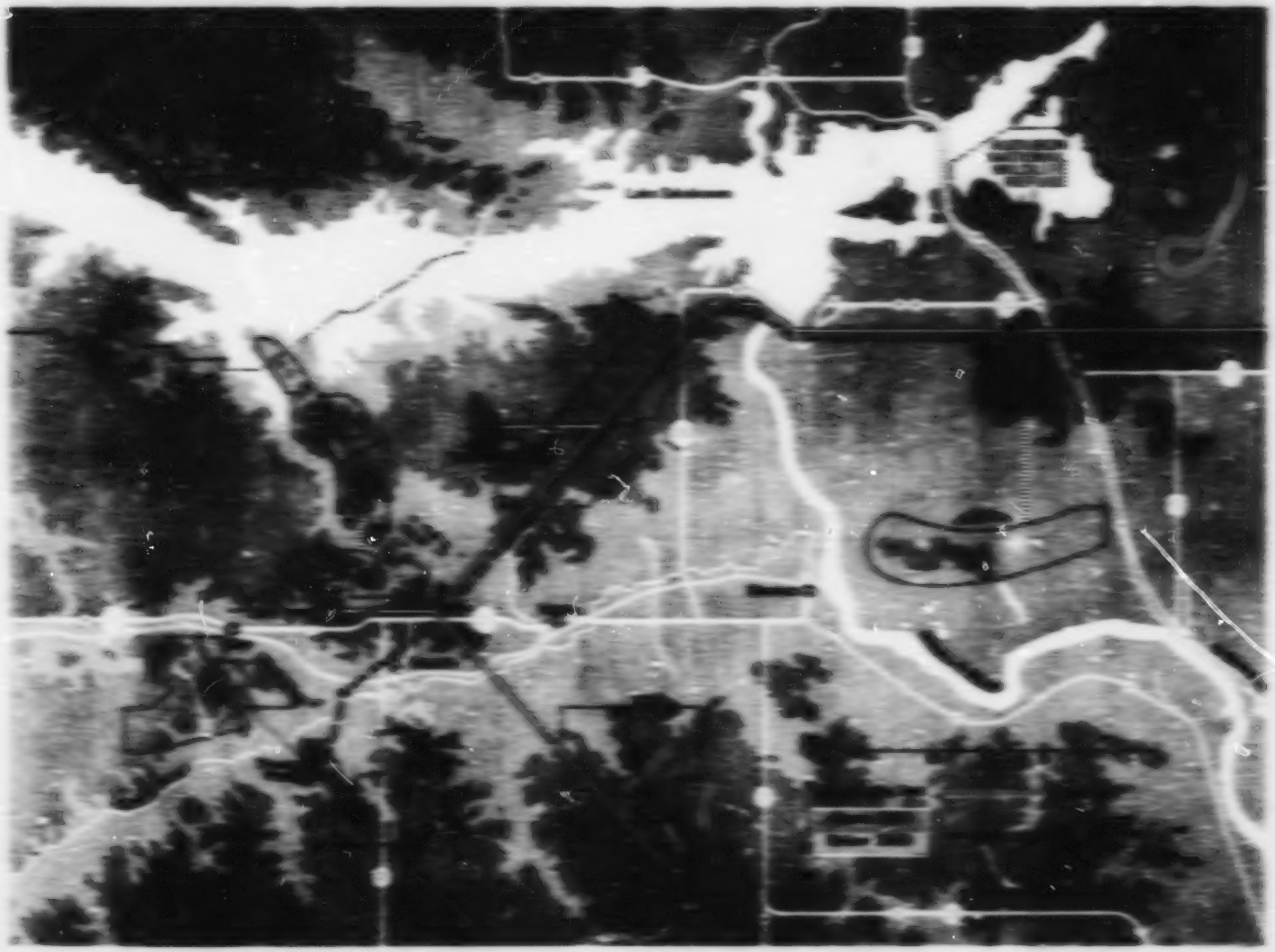

FIGURE 11-2: ENERGY FACILITIES IN THE BEULAH SCENARIO

TABLE 11-1: RESOURCES AND HYPOTHESIZED FACILITIES AT BEULAH

Resources Coal^a (billions of tons) [illegible] [illegible] Proved Reserves [illegible]	Characteristics Coal^b Heat Content [illegible] Btu's/lb Moisture [illegible] % Volatile Matter [illegible] % Fixed Carbon [illegible] % Ash [illegible] % Sulfur 0.8 %		
Technologies Extraction Coal	Facility Size	Completion Date	Facility Serviced
Five surface mines of varying capacity using draglines	[illegible] MMtpy [illegible] MMtpy [illegible] MMtpy [illegible] MMtpy [illegible] MMtpy	1980 [illegible] 1987 [illegible] 2000	Power Plant Lurgi Lurgi Synthane Synthane
Conversion One [illegible]-MWe power plant consisting of four [illegible]-MWe turbine-generators; [illegible] plant efficiency; [illegible] efficient limestone scrubbers; [illegible] efficient electrostatic precipitator; and wet forced-draft cooling towers	750 MWe 750 MWe 1,500 MWe	1977 [illegible] 1980	
Two Lurgi coal gasification plants operating at [illegible] thermal efficiency; nickel-catalyzed methanation process; Claus plant H₂S removal; and wet forced-draft cooling towers	[illegible] MMscfd [illegible] MMscfd	[illegible] [illegible]	
Two Synthane coal gasification plants operating at [illegible] thermal efficiency; nickel-catalyzed methanation process; Claus plant H₂S removal; wet forced-draft cooling towers	[illegible] MMscfd [illegible] MMscfd	[illegible] 2000	
Transportation Gas Two [illegible]-inch pipelines	[illegible] [illegible] [illegible] [illegible]	[illegible] [illegible]	Lurgi Synthane
Electricity Four extra-high voltage lines	[illegible] kV [illegible] kV [illegible] kV (2 lines)	[illegible] [illegible] 1980	Power Plant Power Plant Power Plant

Btu's/lb = British thermal units per pound
H₂S = hydrogen sulfide
kV = kilovolts
MMscfd = million standard cubic feet per day
MMtpy = million tons per year
MWe = megawatts-electric

[a] Anderson, Donald L. Regional Analysis of the U.S. Electric Power Industry, Vol. [illegible]: Coal Resources in the United States. For U.S. Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 197[illegible]. [illegible]

[b] [illegible], [illegible], [illegible], and [illegible]. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience. [illegible] Contract No. [illegible]. Dayton, Ohio: Monsanto Research Corporation, 197[illegible]. Since these values represent averages, they do not sum precisely to 100.

way to intensive livestock grazing and cultivation, and aquatic habitats have been modified by reservoirs. Groundwater and surface water are available in the area, the latter primarily from the Missouri River and the Garrison Reservoir. Air quality is generally good with good dispersion conditions prevailing throughout the year. Selected characteristics of the area are summarized in Table 11-2. Elaborations of these characteristics are introduced as required to explain the impact analyses reported in this chapter.

TABLE 11-2: SELECTED CHARACTERISTICS OF THE BEULAH AREA

Environment	
Elevation	1,700-2,200 feet
Precipitation (annual)	17 inches
Temperatures	
January minimum	-3°F
July maximum	86°F
Vegetation	Mixed-grass prairie with stream-side woodlands
Social and Economic[a]	
Land Ownership	Private ownership in excess of 97%
Land Use	97% agriculture
Population Density	5.9 per square mile
Unemployment	3.6%
Income	$11,270 per capita annual
County Government	Board of Commissioners
City (Beulah) Government	Mayor-Council
Taxation	Primarily property tax
County Revenues (1972)	$750,000

[a] Characteristics for Mercer County, 1975 currency.

11.2 AIR IMPACTS

11.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Beulah area is currently affected by four lignite-fired power plants ranging from 13.5 MWe (megawatts-electric) to 23.5 MWe. Measurements of criteria pollutant[1] concentrations taken in the Beulah area do not indicate any violations of the established standards for particulates, sulfur dioxide (SO_2), or nitrogen dioxide (NO_2). Based on these measurements, annual average background levels for the above mentioned pollutants have been estimated (in micrograms per cubic meter [$\mu g/m^3$]) as: particulates, 39; SO_2, 14; and NO_2, 4.[2]

B. Meteorological Conditions

The worst dispersion conditions for the Beulah area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), persistent wind direction, and relatively low mixing depths.[3] These conditions are likely to increase concentrations of pollutants from both ground-level and elevated sources.[4] Since worst-case conditions differ at each site, predicted annual average pollutant levels vary among sites even if pollutant sources are identical. Prolonged periods of air stagnation are uncommon in the Beulah area because of moderate to strong winds, relatively high mixing depths, and a general lack of stagnating high-pressure systems.

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[1] Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, non-methane hydrocarbons, nitrogen oxides, oxidants, particulates, and sulfur dioxide. The term "hydrocarbons" is generally used to refer to non-methane HC.

[2] These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are assumed relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

[3] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[4] Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emissions.

However, meteorological conditions in the area are generally unfavorable for pollution dispersion approximately 30 percent of the time. Hence, plume impaction[1] and limited mixing of plumes caused by air inversions at plume height can be expected with some regularity.[2] Favorable dispersion conditions associated with moderate winds and large mixing depths are expected less than 15 percent of the time.

The pollution dispersion potential for the Beulah area may be expected to vary considerably with the season and time of day. Poor dispersion most frequently occurs in fall and winter mornings due largely to lower wind speeds and mixing depths.

11.2.2 Emission Sources

The primary emission sources in the Beulah scenario are a power plant, four conversion facilities (two Lurgi and two Synthane), supporting surface mines, and those associated with population increases. Pollution from energy-related population increases was estimated from available data on average emissions per person in several western cities.[3] Most mine-related pollution originates from diesel engine combustion products, primarily nitrogen oxides (NO_x), hydrocarbons (HC), and particulates. Although dust suppression techniques are hypothesized in the scenario, some additional particulates will come from blasting, coal piles, and blowing dust.[4]

The hypothetical power plant in this scenario has four 750-MWe boilers, each with its own stack.[5] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2 and 40 percent of the NO_2. The plant has two 75,000-barrel storage tanks, with standard floating roof construction, each of which will emit up to 0.7 pound of HC per hour.

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[1] Plume impaction is the limited atmospheric mixing of stack plumes because of containment by elevated terrain and stable air conditions.

[2] See National Climatic Center. *Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities*. Ashville, N.C.: National Climatic Center, 1975.

[3] Refer to the Introduction to Part II for identification of these cities and references to methods used to model urban meteorological conditions. This scenario models only concentrations for Beulah, North Dakota.

[4] The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency is investigating this question and will be used to inform further impact analysis.

[5] Stacks are 500 feet high, have an exit diameter of 33.1 feet, mass flow rates of 3.10 x 10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

The power plant and the two coal conversion facilities are cooled by wet forced-draft cooling towers. Each of the various cells in the cooling towers circulates water at a rate of 15,330 gallons per minute and emits 0.01 percent of its water as a mist.[1] The circulating water has a total dissolved solids content of 10,000 parts per million. This results in a salt emission rate of 21,200 pounds per year for each cell.[2]

Table 11-3 gives emissions of the five criteria pollutants for each of the three facilities. In all three cases, most

TABLE 11-3: EMISSIONS FROM FACILITIES
(pounds per hour)

Facility[a]	Particulates	SO_2	NO_x	HC	CO
Power Plant					
Mine	24	16	215	130	25
Plant	3,012	13,848	21,084	652	2,176
Lurgi					
Mine	7	5	66	8	40
Plant	511	681	2,407	49	321
Synthane					
Mine	8	5	69	8	42
Plant	685	970	2,108	58	196

CO = carbon monoxide

HC = hydrocarbons

NO_x = nitrogen oxides

SO_2 = sulfur dioxide

[a] The Lurgi and Synthane gasification facilities each produce 250 million standard cubic feet per day, and each plant has three stacks. A detailed description of each plant is contained in the Energy Resource Development Systems description to be published as a separate report in 1977.

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[1] These efficiencies were hypothesized as reasonable estimates of current industrial practices.

[2] The power plant has 64 cells, each Lurgi plant has 11, and each Synthane plant has 6.

emissions are attributable to the plants, rather than the mines. The largest single contributor to total emissions for all pollutants is the power plant. For all five pollutants, the Lurgi plant has the smallest total emissions.

11.2.3 Impacts

A. Impacts to 1980

1. Pollution from Facilities

Construction of the hypothetical power plant and Lurgi gasification plant will begin in this period, with the power plant becoming fully operational by 1980. Air quality impacts associated with the construction phases of these plants or those coming on-line by 1990 or 2000 will be minimal. However, construction processes may increase wind-blown dust, causing possible periodic violations of 24-hour ambient particulate standards.

Table 11-4 summarizes the concentrations of four pollutants predicted to be produced by the power plant and its supporting surface mine. These pollutants (particulates, SO_2, NO_2, and HC) are regulated by federal and North Dakota state ambient air quality standards (also shown in Table 11-4). This information shows that the typical and peak concentrations associated with the plant and with the plant and mine combination, when added to existing background levels, will be well below all federal and most state ambient standards. Only the North Dakota 1-hour SO_2 and NO_2 standards will be violated; however, the NO_2 standards will be exceeded by a factor of 7.

Table 11-4 also lists Non-Significant Deterioration (NSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] "Class I" is intended to designate the cleanest areas, such as national parks and forests.[2] Typical concentrations of the short-term (less than 24-hours) averaging time for SO_2 from the power plant and mine combination will exceed allowable Class I

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[1] Non-Significant Deterioration standards apply only to particulates and sulfur dioxide.

[2] The Environmental Protection Agency initially designated all Non-Significant Deterioration areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class III. A Class II designation is for areas which have moderate, well-controlled energy, or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III areas allow deterioration to the level of secondary standards.

TABLE 11-4: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]					Standards[b]				
	Background	Typical	Peak			Ambient			Non-Significant Deterioration	
			Plant	Plant and Mine	Beulah	Primary	Secondary	North Dakota	Class I	Class II
Particulate										
Annual	39		0.3	1.4	0.9	75	60	60	5	10
24-hour		3.7	26	26	23	260	150	150	10	30
SO_2										
Annual	26		1.3	1.9	3.6	80		60	2	15
24-hour		6.2	111	111	61	365		260	5	100
3-hour		15	600	600	300		1,300		25	700
1-hour			460	860				715		
NO_2[c]										
Annual	6	90	2.3	22	3	100	100	100		
1-hour			[illegible]	[illegible]				200		
HC[d]										
3-hour		6.9	41	70	26	160	160	160		

HC = hydrocarbons
NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered to be the best estimates of worst-case background levels. Concentrations over Beulah are largely attributable to the plant.

[b] "Primary and Secondary" refer to Federal ambient air quality standards designed to protect against public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all NO_x from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

increments. In addition, peak concentrations attributable to the power plant and the plant and mine combination will far exceed the 24-hour and 3-hour Class I increments for both particulates and SO_2. Class I increments for SO_2 (24-hour and 3-hour averaging times) will be exceeded by a factor greater than 30. The peak SO_2 concentration for the power plant and the plant and mine combination will also cause the Class II 24-hour increment to be exceeded.

Since the plant exceeds some Class I increments, it would have to be located far enough away from any such areas so that emissions will be diluted by atmospheric mixing to allowable concentrations prior to reaching any Class I area. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I and Class II areas.[1] Current Environmental Protection Agency (EPA) regulations would require a 72-mile buffer zone between the power plant and a Class I area boundary. Since there are no current or potential Class I areas within the power plant's buffer zone, no Class I standards are expected to be violated.

2. Pollution from the Town

The town of Beulah is projected to grow from a 1975 population of 1,350 to 2,300 by 1980. This increase will contribute to increases in pollution concentrations from urban sources. Table 11-5 shows predicted concentrations of the five criteria pollutants measured at the center of the town and at a point 3 miles from the center of town.

When concentrations from urban sources only are added to background levels, no federal or North Dakota state ambient standards will be exceeded.

B. Impacts to 1990

1. Pollution from Facilities

The Lurgi gasification plant will become operational in 1982. A second Lurgi plant will be constructed and become operational in 1987. Table 11-6 summarizes typical and peak pollution concentrations once these developments become operational. Peak concentrations from these new plants are not

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[1] Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area "wind roses", which show wind direction patterns and strengths for various areas and seasons. Hence, the direction of Non-Significant Deterioration areas from energy facilities will be critical to the size of the buffer zone required.

TABLE II-5: POLLUTION CONCENTRATIONS AT BEULAH
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]							Standards[b]		
		Mid-Town Point			Rural Point					
	Background	1980	1985	1995	1980	1985	1995	Primary	Secondary	North Dakota
Particulates										
Annual	30	5	7	8	1	1	2	75	60	60
24-hour		27	28	27	27	28	27	260	150	150
SO_2										
Annual	26	3	4	5	0	0	1	80		60
24-hour		9	14	15	9	14	15	365		260
3-hour		15	26	27	11	26	27		1,300	
1-hour		18	29	32	18	29	32			715
NO_2[c]										
Annual	4	8	11	14	1	1	2	100	100	100
1-hour		56	79	97	56	79	97			200
HC[d]										
3-hour		120	180	210	120	180	210	160	160	160
CO										
8-hour		586	792	926	586	792	926	10,000	10,000	10,000
1-hour		829	1,290	1,514	829	1,290	1,514			

CO = carbon monoxide
HC = hydrocarbons

NO_2 = nitrogen dioxide
SO_2 = sulfur dioxide

[a] There are no direct ground-level concentrations from other sources. Background concentrations are taken from Table 7-6. "Rural point" are measurements taken 3 miles from the center of town.

[b] "Primary and Secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 50 percent of nitrogen oxide from urban sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

TABLE 11-6: POLLUTION CONCENTRATIONS FROM LARGE PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentration^a						Standards^b				
			[illegible]				Ambient			Non-Significant Deterioration	
					[illegible]						
	Background	Typical	Plant	Plant and Mine	Large I	Large II	Primary	Secondary	North Dakota	Class I	Class II
Particulate											
Annual	10		0.3	0.3	0.1	0.2	75	60	60	5	19
24-hour		2.5	1.9	5.7	1.9	2.8	260	150	150	10	37
SO_2											
Annual	10		0.4	0.6	0.2	0.4	80		60	2	15
24-hour		1.6	7.2	6.9	2.5	2.1	365		260	5	100
3-hour		7.6	35	35	8.1	33		1,300		25	700
1-hour		9.3	63	60					715		
NO_2^c											
Annual	6	22	0.5	1.8	0.5	0.5	100	100	100		
1-hour			240	237					200		
HC^d											
3-hour		0.9	2.4	26	1.1	4.9	160	160	160		

HC = hydrocarbons

NO_2 = nitrogen dioxide

SO_2 = sulfur dioxide

[a] These are predicted ground-level concentrations from the hypothetical large plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over [illegible] are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 24.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

expected to cause violations of federal or North Dakota state ambient air standards.[1]

These facilities will easily meet all Class II PSD increments, although the Class I increment for 24- and 3-hour SO_2 concentrations will be exceeded slightly. Due to the relatively small nature of the PSD violation, the EPA requires a Class I buffer zone of only 13.1 miles for each plant. Since there are no current or proposed Class I areas within these buffer zones, no significant deterioration problems are anticipated.

2. Pollution from the Town

Beulah's population is predicted to grow to 4,000 by 1985, then to decline to 2,200 by 1990. The concentrations of urban pollutants for 1985 are shown in Table 11-5. The 3-hour HC concentrations predicted for 1985 will violate federal primary and secondary standards as well as North Dakota air quality standards. All other criteria pollutant concentrations are expected to be well within established standards.

C. Impacts to 2000

1. Pollution from Facilities

Two Synthane gasification plants will become operational between 1990 and 2000. Table 11-7 gives typical concentrations from the plant, peak concentrations from the plant, and peak concentrations from the combination of the plant and its surface mine. These data show no violations of any federal or state ambient air standards from the Synthane facilities.[2]

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[1] Interactions of the pollutants from the plants are minimal because of the hypothetical distances between them. If the wind blows directly from one plant to the other, plumes will interact. However, the resulting concentrations would be less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentration). The Lurgi plant is too far away to affect peak concentrations. Had the plants been sited closer together, the probability of interactions would increase. Sensitivity analysis of this siting consideration will be done during the remainder of the study.

[2] Interactions between the Synthane plants, power plant, and Lurgi plants will cause increases in annual peak concentrations. However, these increases are expected to be relatively small, (less than 3 micrograms for particulates and sulfur dioxide and less than 15 micrograms for nitrogen dioxide and should not violate any standards.

TABLE 11-7: POLLUTION CONCENTRATIONS FROM SYNFUELS PLANT/MINE COMBINATION
(micrograms per cubic meter)

Pollutant Averaging Time	Concentrations[a]						Standards[b]				
			Peak		[illegible] Synfuels		Federal			Non-Significant Deterioration	
	Background	Typical	Plant	Plant and Mine	1	2	Primary	Secondary	North Dakota	Class I	Class II
Particulate											
Annual	29		2.2	3.4	1.2		75	60	60	5	19
24-hour		1.7	4.2	6.7	4.2	1	260	150	150	10	37
SO_2											
Annual	26		0.6	1.5	1.1	0.3	80		60	2	20
24-hour		2.2	4.3	7.5	3.8	1.3	365		260	5	91
3-hour		8.7	39	39	22	4		1,300		25	512
1-hour		22	49	49					715		
NO_2[c]											
Annual	6			1.4	2.6	0.6	100	100	100		
1-hour		37	96	237					200		
HC[d]											
3-hour		2.1		21	1.2	0.2	160	160	160		

HC = Hydrocarbons

NO_2 = Nitrogen Dioxide

SO_2 = Sulfur Dioxide

[a] These are predicted ground-level concentrations from the hypothetical Synfuels gasification facility and supporting mine. Annual average background levels are considered to be the best estimates of short-term background levels. Concentrations near Beulah are largely attributable to the plant.

[b] "Primary and Secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. Non-Significant Deterioration standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These standards are discussed in detail in Chapter 14.

[c] It is assumed that all nitrogen oxide from plant sources is converted to NO_2. Refer to the Introduction to Part II.

[d] The 3-hour HC standard is measured at 6-9 a.m.

Peak concentrations from the Synthane plants will exceed Class I PSD increments for 24-hour and 3-hour SO_2 levels. These violations will require an 10.6-mile buffer zone between each plant and any designated Class I area.

2. Pollution from the Town

During the 1990-2000 decade, the town of Beulah will again record an increase and then a decrease in population. The maximum population will reach 4,800 in 1995, and increased pollution concentrations will be associated with this growth (Table 11-5). As was the case in 1985, only 3-hour HC levels will exceed any federal or state ambient air standards. All other pollutant concentrations fall well within existing air quality standards.

11.2.4 Other Air Impacts

Seven additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of problems and how energy development may affect the extent of the problems during the next 25 years. These categories of potential impacts are sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.[1]

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[1] No analytical information is currently available on the source and formation of nitrates. If information does become available, nitrates may be analyzed during the remainder of the project. See: Hazardous Materials Advisory Committee. *Nitrogenous Compounds in the Environment*. U.S., Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

A. Sulfates

Very little is known about sulfate concentrations likely to result from western energy development. However, one study suggests that for oil shale retorting, peak conversion rates of SO_2 to sulfates in plumes are less than 1 percent.[1] Applying this ratio to plants in the Beulah scenario results in peak 24-hour sulfate concentrations of less than 1 μg/m³. This is well below EPA's suggested danger point of 12 μg/m³ for a 24-hour average.[2]

B. Oxidants

Oxidants (which include compounds such as ozone, aldehydes, peroxides, peroxyacyl nitrates, chlorine, and bromine can be emitted from specific sources or formed in the atmosphere. For example, oxidants can be formed when HC combine with NO_x. Too little is known about the actual conversion processes that form oxidants to be able to predict concentrations from power plants. However, the relatively low peak concentrations of HC from the power plant and its associated mine (50 μg/m³) suggest that an oxidant problem will probably not result from that source alone. An oxidant problem would more likely result from the combination of background HC and the high levels of NO_x emitted in the power plant plume. Since background HC levels are unknown, the extent of this problem has not been predicted.

In only one of several cases investigated[3] did oxidant formation from coal gasification plants exceed federal standards. However, these cases are not comparable to the Lurgi and Synthane facilities hypothesized in this scenario, and thus levels of oxidants formed from the combination of HC and NO_2

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[1] Nordsieck, R., et al. Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States, Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975. This study assumed that sulfur dioxide (SO_2) in the plumes was converted to sulfate at the rate of 1 percent per hour independent of humidity, clouds, or photochemically related reaction intensity. Reported results indicate peak sulfate levels ranging from 0.1 to 1.6 percent of the corresponding peak SO_2 levels from oil shale retorting. Recent work in Scandinavia suggests that acid-forming sulfates arriving in Norway are complex ammonium sulfates formed by a catalytic and/or photochemical process which varies with the season.

[2] Ibid.

[3] Ibid.

were not predicted. Concentrations of HC in this scenario are much smaller than those found in the one case in which standards were violated. Although the NO_2 levels are roughly equal, violation of oxidant concentrations from the gasification facilities in this scenario are not expected, based on this one source of information.

HC concentrations over Beulah may create an oxidant problem because they are expected to reach levels somewhat in excess of federal and state standards. Since oxidant formation may occur relatively slowly (i.e. one or more hours), this problem will be less when wind conditions move pollutants rapidly away from the town. The relatively small area of Beulah will also work to lessen the impact of oxidant formation.

C. Fine Particulates

Fine particulates (those less than 3 microns in diameter) are primarily ash and coal particles emitted by the plants.[1] Current information suggests that particulate emissions controlled by ESP's have a mean diameter of less than 5 microns, and uncontrolled particulates have a mean diameter of about 10 microns.[2] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles remaining in plant plumes. The high-efficiency ESP's (99-percent removal) in this scenario are estimated to remove enough coarse particulates so that fine particulates will account for about 50 percent of the total particulate concentrations in plant plumes. This percentage applies to the power plant and Lurgi and Synthane gasification processes. Health effects from fine particulates are discussed in Section 12.6.

D. Long-Range Visibility

One impact of very fine particulates (0.1-1.0 microns in diameter) is that they reduce long-range visibility. Particulates suspended in the atmosphere scatter light and thus with increased concentrations and/or distances will eventually reduce the contrast between an object and its background below the level required by the human eye to distinguish the object from its background. Estimates of visual ranges for this scenario are based on empirical relationships between visual distance and fine particulate concentrations.[1]

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[1] Fine particulates produced by atmospheric chemical reactions take long enough to form so they occur long distances from the plants.

[2] Fifty percent of the mass is contained in particles this diameter. Eppright, B.R., *et al.* *A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station*, Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

Visibility in the region of this scenario is assumed to average about 60 miles. The greatest reduction in average visibility will occur roughly along a north-south line through Beulah. As the facilities in this scenario become operational, average visibility will eventually decrease to 54 miles by the year 2000. Air stagnation episodes will cause substantially greater reductions.

E. Plume Opacity

Fine particulates make plumes opaque in the same way they limit long-range visibility. Although ESP's will remove enough particulates for the power plant in this scenario to meet emission standards, stack plumes will still exceed the 20-percent opacity standard.[2] Thus, plumes would probably be visible at the stack exit and for some distance downwind. Although no opacity standards exist for gasification plants, the Lurgi and Synthane plants all have more than one stack which could produce plumes with greater than 20-percent opacity.

F. Cooling Tower Salt Deposition

Estimated salt deposition rates from cooling tower drift for the facilities in this scenario are shown in Table II-8. These rates are relatively low and decrease rapidly beyond 1.1 miles. Some interaction of salt deposition from the various plants will occur. For example, one area of interaction around the periphery of the second Lurgi gasification plant will receive a cumulative total of 7 pounds per acre per year (lb/acre/yr), and the immediate vicinity of the second Lurgi plant

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[1] Charlson, R.J., N.C. Ahlquist, and H. Horvath. "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." Atmospheric Environment, Vol. 2 (September 1968), pp. 455-64. Since the model is designed for urban areas, its use in rural areas yields results that are only approximate.

[2] The Federal New Source Performance Standard for electric utilities requires both that plume opacity be less than 20 percent and that particulate emissions not exceed 0.1 pound of particulates per million British thermal unit's heat input. The plume opacity requirements are not as likely to be as strictly met as the particulate emissions standard because it would require removal of 99.9 percent of all plume particulates, which would increase electrostatic precipitator costs.

TABLE 11-8: SALT DEPOSITION RATE

Plant	Average Salt Deposition Rate (pounds per acre per year)		
	1.1 miles[a]	1.1-9.3 miles	9.3-27.8 miles
Power Plant	91	5.8	0.2
Lurgi Gasification (each)	16	1	0.03
Synthane Gasification (each)	8.5	0.6	0.02

[a] Diameter of circles bounding the area subject to the salt deposition rate.

will receive an average of about 22 lb/acre/yr. The effect of salt on the area will depend on soil conditions, rainfall, and existing vegetation.

G. Cooling Tower Fogging and Icing

The frequency of fogging or icing potential from cooling towers in the Beulah area is generally low. On occasion, however, plumes capable of causing these conditions have been observed extending several thousand feet from the towers. Since several highways are in the vicinity of the cooling towers, hazardous driving conditions from ice and fog will occasionally occur.

11.3.5 Summary of Air Impacts

A. Air Quality

Five new facilities are projected for the Beulah area by the year 2000. No federal ambient standards will be violated by any of the facilities, but North Dakota's 1-hour SO_2 and NO_2 standards will be violated by emissions from the power plant.

Each of the facilities will violate several PSD allowable increments. Peak concentrations from the power plant will exceed Class II increments for 24-hour SO_2 and Class I increments for 24-hour and 3-hour SO_2. The power plant will also exceed Class I increments for 24-hour particulates. In addition, typical concentrations from the plant will violate one short-term SO_2 increment. Peak concentrations from the Lurgi and Synthane plants will violate Class I increments for expected 24-hour and 3-hour SO_2 levels. Because of these violations, each of the facilities will require buffer zones. The largest buffer zone will be required for the power plant (72 miles).

TABLE 11-9: CONCENTRATIONS FROM MINIMAL EMISSION CONTROLS[a]
(micrograms per cubic meter)

SO_2 Averaging Time	Concentration	Standards		North Dakota
		Primary	Secondary	
Annual	3.4	80		60
24-hour	292	365		260
3-hour	1,806		1,300	
1-hour	2,252			715

SO_2 = sulfur dioxide

[a] These are maximum concentrations which assume 40-percent SO_2 removal, which would meet the federal New Source Performance Stan- of 1.2 pounds of SO_2 per million British thermal units of heat input.

followed by the Synthane plants (18.6 miles), and the Lurgi plants (13.1 miles).

Population increases in Beulah will add to existing concentrations and create possible pollution problems. By 1985, both federal and North Dakota ambient standards for 3-hour HC will be violated.

Several other categories of air impacts have received only preliminary attention. Although our information suggests that oxidant problems are unlikely, they may occur (as may problems from fine particulates). Plumes from the stacks at all facilities will be visible, and power plant stack may exceed the 20-percent opacity standard. Long-range visibility will be reduced from the current average of 60 miles to about 54 miles by the year 2000.

B. Alternative Emission Controls

Pollution concentrations from the power plant would vary if emission control systems with other efficiencies were used. For example, Table 11-9 gives SO_2 pollution concentrations which would result if the plant used only enough control to meet most New Source Performance Standards; that is, if the plant removed only 40 percent of the SO_2 rather than the 60 percent currently hypothesized in this scenario.[1] These data show that resulting

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[1] These efficiencies would probably not meet the NSPS opacity standard. New Source Performance Standards do not exist for gasification plants. The Lurgi and Synthane plants meet all Class II increments in this scenario.

TABLE 11-10: ALTERNATIVES FOR MEETING CLASS II INCREMENTS

Pollutant Averaging Time	Required Emission Removal (%)	Plant Capacity (megawatts-electric)
Sulfur Dioxide		
Annual	0	> 3,000
24-hour	83	> 2,670
3-hour	80	> 3,000
Particulates		
Annual	67	> 3,000
24-hour	98.8	3,000

> = is greater than.

concentrations would violate either federal or North Dakota ambient standards for all but the annual averaging time.

Other alternatives are for the plants to increase the efficiency of emission controls or to reduce total plant capacity to meet all N&D Class II increments. The information in Table 11-10 shows that 83-percent SO_2 removal and 98.8-percent particulate removal would be required to meet all allowable Class II increments.[1] Alternatively, the plant could meet Class II requirements by reducing output to 2,670 MWe.[2]

C. Data Availability

Data availability and quality have limited the impact analysis reported in this chapter. These factors have primarily affected estimation of long-range visibility, plume opacity, oxidant formation, sulfates, nitrates, and areawide formation of trace materials. Expected improvements in data and analysis capacities include:

1. Improved understanding of areawide pollutant dispersion by monitoring currently being conducted under the auspices of the EPA.

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[1] Removal rates of 83 percent for sulfur dioxide and 98.9 percent for particulates are possible using existing technology. More attention will be given to technological feasibility of highly efficient control systems during the remainder of the project.

[2] This projection assumes concentrations are directly proportional to megawatt output.

2. Improved understanding of pollutant emissions from electrical generation, gasification, and liquefaction. This includes the effect of pollutants on visibility.

3. More information on the amounts and reactivity of trace elements from coals for alternative conversion processes. This would improve estimates of fallout and rainout from plumes.

11.3 WATER IMPACTS

11.3.1 Introduction

The main source of water in the Beulah scenario area is the Upper Missouri River (see Figure 11-3). Water is available either from the rivers in the area or from Lake Sakakawea. Although of lesser importance, the Knife River is also capable of supplying water to some energy developments. Annual rainfall averages about 15 inches, and annual snowfall averages about 36 inches.

This section identifies the sources and uses of water required for energy development, the residuals that will be generated, and the water availability and quality impacts that are likely to result.

11.3.2 Existing Conditions

A. Groundwater

The Beulah scenario area is located on the southeastern edge of the Williston Basin, a large sedimentary basin encompassing much of western North Dakota and eastern Montana. Groundwater is available from deep bedrock aquifers, shallow sandstone aquifers, lignite aquifers, and alluvial aquifers in the area.[1] Deeper, potentially highly productive aquifers, such as the Dakota or the Madison, are important regionally but apparently do not contain potable water in the Beulah area.

Deep bedrock aquifers include the Fox Hills and basal Hell Creek aquifer and the upper Hell Creek and lower Cannonball-Ludlow aquifer, with the former being deeper. Wells in the lower aquifers are as much as 1,500 feet deep and yield up to 150 gallons per minute (gpm) while the upper aquifer wells are about 500-800 feet deep with maximum yields of 100 gpm. The water quality of the two aquifers is quite similar; both

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[1] Croft, M.G. *Ground-Water Resources, Mercer and Oliver Counties, North Dakota.* North Dakota Geological Survey Bulletin 56, Part III. Grand Forks, N.D.: North Dakota Geological Survey, 1974.

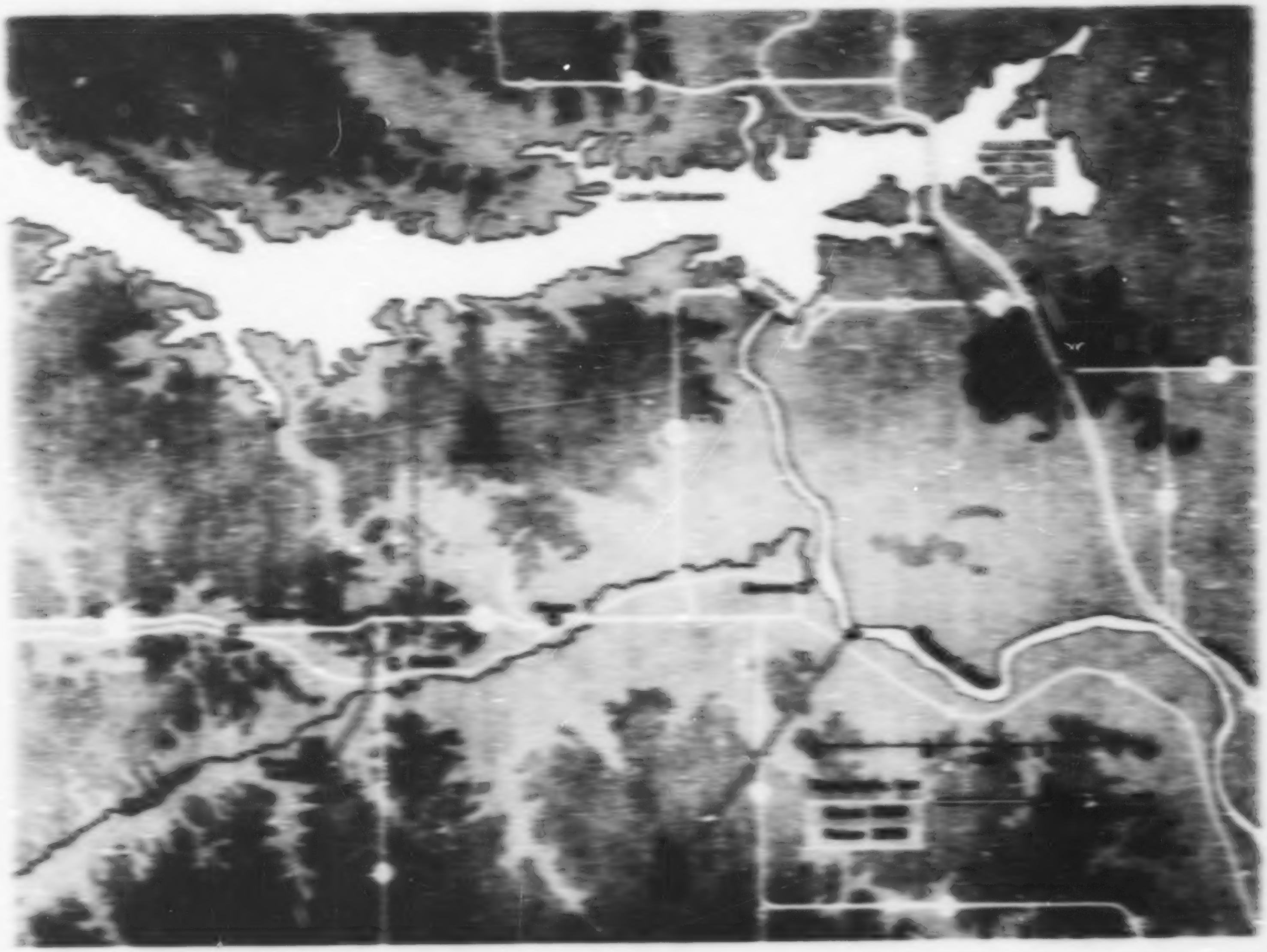

FIGURE 11-3: WATER PIPELINES FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

contain a total dissolved solids (TDS) content of about 1,500 milligrams per liter (mg/ℓ). (The U.S. Geological Survey defines 1,000-3,000 mg/ℓ as slightly saline.) Both aquifers are currently tapped for domestic livestock uses, with the lower aquifer also being used for municipal supplies.

The lower Tongue River Formation aquifer is in shallow sandstone and is separated from the deeper Hell Creek-Cannonball-Ludlow aquifer by a considerable thickness of relatively impermeable siltstone and claystone beds. The formation is only about 150 feet thick, and well yields are only about 5 gpm. The water contains sodium bicarbonate with a TDS of 1,400-1,700 mg/ℓ. The aquifer is tapped by wells for domestic and stock purposes.

Lignite bed aquifers are also used for domestic and stock purposes. Well yields are generally less than 10 gpm, and TDS concentration is generally over 1,000 mg/ℓ.

Alluvial aquifers are present along the intermittent and perennial streams in the Beulah area. The most important of these are the Knife River and Missouri River aquifers and those along Goodman, Antelope, Elm, and Square Butte Creeks. Thicknesses range generally from 100 to 200 feet. The alluvial aquifers are the most productive in the Oliver County area, generally yielding more than 500 gpm.[1] Also, water quality is generally better than in the bedrock aquifers. TDS concentration ranges from about 500 to about 1,700 mg/ℓ. Water from alluvial aquifers is used for a wide variety of purposes.

B. Surface Water

The illustrative energy facilities in the Beulah scenarios are located generally south of the eastern portion of Lake Sakakawea in the Upper Missouri drainage basin. Garrison Dam, which is near Riverdale, impounds the Missouri River to form Lake Sakakawea. The lake is used for flood control, irrigation, power, recreation, navigation, and as a water supply source for municipal and industrial users. Reservoir characteristics are shown in Table 11-11.

Flows in the Missouri River are greatly affected by conditions in the Yellowstone River Basin, which supplies about one-half of the average annual flow at Garrison Dam. Pertinent data for flow at Bismarck are shown in Table 11-12.

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[1] Croft, M.G. Ground-Water Resources, Mercer and Oliver Counties, North Dakota. North Dakota Geological Survey Bulletin 56, Part III. Grand Forks, N.D.: North Dakota Geological Survey, 1974.

TABLE 11-11: RESERVOIR CHARACTERISTICS - LAKE SAKAKAWEA[a]

Location of Garrison Dam	Near Riverdale, North Dakota at river mile 1,389.9	
Contributing drainage area	180,050	square miles
Approximate length	178	miles
Maximum width	14	miles
Average width	3	miles[b]
Maximum operating pool elevation and area	1,775 189,000	feet above mean sea level; acres
Inactive storage between 1,775 and 1,673 feet above mean sea level	5	million acre-feet
Total gross storage between 1,854 and 1,673 feet above mean sea level	24.6	million acre-feet
Maximum discharge	368,000	cubic feet per second
Minimum discharge[c]	1,380	cubic feet per second
Average discharge	21,500	cubic feet per second
Power production plant capacity dependable capacity	 500 302	 megawatts-electric megawatts-electric
Surface fluctuation[b]	15 30	feet average feet maximum in recent years

[a] Missouri Basin Inter-Agency Committee. The Missouri River Basin Comprehensive Framework Study. Denver, Colo.: U.S., Department of the Interior, Bureau of Land Management, 1971.

[b] Northern Great Plains Resources Program, Water Work Group. Water Quality Subgroup Report. Discussion Draft. Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1974.

[c] U.S., Department of the Interior, Bureau of Reclamation, Upper Missouri Region. Final Environmental Statement: Initial Stage, Garrison Diversion Unit, Pick-Sloan Missouri Basin Program, North Dakota. Billings, Mont.: Bureau of Reclamation, 1975.

TABLE II-32: STREAM FLOW DATA IN THE BEULAH SCENARIO AREA

River and Location	Years of Record	Drainage Area (sq. mi.)	Minimum Flow (cfs)	Maximum Flow (cfs)	Average Flow (cfs & acre-ft/yr)
Missouri River at Bismarck	45	186,400	1,800	500,000	21,720 15,740,000
Knife River at Hazen	47	2,240	3	35,300	181 131,100
Square Butte Creek Below Center	8	146	0	9,700	14.2 10,290
Spring Creek at Zap	28	549	0	6,130	43.8 31,730
West Branch Otter Creek near Beulah	8	35.5	0	23,700	4.1 2,960

cfs - cubic feet per second

TABLE 11-13: WATER USES ABOVE LAKE SAKAKAWEA[a] (1965)

Use	Water Requirement (acre-ft/yr)
Irrigation	436,000
Municipal and Rural Domestic	8,700
Mineral	1,800
Thermal Electric Power	9,600
Other Industry	12,000
Livestock	4,200
Total	472,000

[a] Data cover area above the confluence of the Yellowstone and Missouri Rivers, just upstream of Lake Sakakawea.

Another significant perennial river in the scenario area is the Knife River, which runs east through Beulah and Hazen to its confluence with the Missouri River below Garrison Dam. The Knife River is part of the Western Dakota Subbasin. Stream flow and other characteristics of the Knife River are shown in Table 11-12. Available data on local creeks are also shown in Table 11-12. The annual water uses reported for this area in 1976 are shown in Table 11-13.[1] The Corps of Engineers has estimated that water will be available to supply both irrigation and energy users through the year 2020.[2] However, releases to sustain navigation may be curtailed under some conditions.

Water quality in Lake Sakakawea is relatively good. Measurements have been made both in the lake and downstream of Garrison Dam. Some of these data are reported in Table 11-14 so that a specific water user can make an evaluation of the suitability of local water quality as it pertains to a particular use. Water quality data for the Knife River is scarce, although there are known high silt and nutrient loads. The nutrients that accompany the silt are related to agricultural fertilizer uses. These nutrients increase aquatic plant growth which reduces fish

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[1] Missouri Basin Inter-Agency Committee. *The Missouri River Basin Comprehensive Framework Study*. Denver, Colo.: U.S., Department of Interior, Bureau of Land Management, 1971.

[2] U.S., Army, Corps of Engineers, Missouri River Division, Reservoir Control Center. *Missouri River Main Stem Reservoirs Long Range Regulation Studies*, Series 1-74. Omaha, Nebr.: Corps of Engineers, 1974.

TABLE 11-34: WATER QUALITY DATA FOR THE BEULAH SCENARIO
(milligrams per liter)

[illegible]

population. Because of these conditions, there is almost no sport fishing in the upper Knife River Basin, although the lower river is a good sport fishery. Water quality parameters have been compiled for area streams from several locations and are shown on Table 11-14.

The availability of water to all the illustrative energy facilities is largely controlled by interstate compacts that govern water use in areas above Lake Sakakawea.[1] Inasmuch as no provision has generally been made in these compacts to govern the location of the withdrawal of water by the owner, allotments can be withdrawn at downstream locations. For instance, Yellowstone River water currently allotted to Wyoming but not being used within that state could be withdrawn as far downstream as Lake Oahe and pumped back to Wyoming. Yet assuming that some allocated water must be passed through, there should be sufficient water available in Lake Sakakawea to supply the scenario energy developments.

A permit for withdrawal of water from Lake Sakakawea must be obtained from the North Dakota State Water Commission. There is currently a moratorium on the issuing of permits from Lake Sakakawea that will be in effect until July 1977. This moratorium has been instituted to allow the legislature to restructure the water allocation program. The availability of water will be decided by the state after allowing for currently allocated water, including the rights of the Bureau of Reclamation to water for the Garrison Diversion Unit.

11.3.3 Water Requirements and Supply

A. Energy Facilities

The water requirements for energy facilities hypothesized for the Beulah scenario are shown in Table 11-15. Two sets of data are presented. The Energy Resource Development System data are based on secondary sources, including impact statements, Federal Power Commission docket, filings and recently published data accumulations.[2] The Water Purification Associates data are from a study on minimum water use requirements and take into

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[1] Belle Fourche River Compact of 1943, 58 Stat. 94 (1944); Yellowstone River Compact of 1950, 65 Stat. 663 (1951).

[2] These ERDS, which are forthcoming as a separate publication, are based on data drawn from: University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975. Radian Corporation. A Western Regional Energy Development Study, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

TABLE 11-15. WATER REQUIREMENTS FOR ENERGY DEVELOPMENT

Use	Size	Requirement[a] (acre/ft/yr)	
		ERDS[b]	WPA[c]
Power Plant	3,000 MWe	42,000	33,400
Coal Gasification (Lurgi) Plants	250 MMscfd each	7,450	3,200
Coal Gasification (Synthane) Plants	250 MMscfd each	10,100	5,100
Coal Mining			1,925

MWe = megawatts-electric
MMscfd = million standard cubic feet per day

[a] Requirements are based on an assumed load factor of 100 percent. Although not realistic for sustained operation, this load factor indicates the maximum water demand for these facilities.

[b] Chapter 3 of White, Irvin L., et al. Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

account the moisture content of the coal being used and local meteorological data.[1]

The use of water required for energy facilities is shown in Figure 11-4. As indicated there, the greatest use for all energy conversion technologies is for cooling. Solids disposal consumes

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[1] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. See Appendix B.

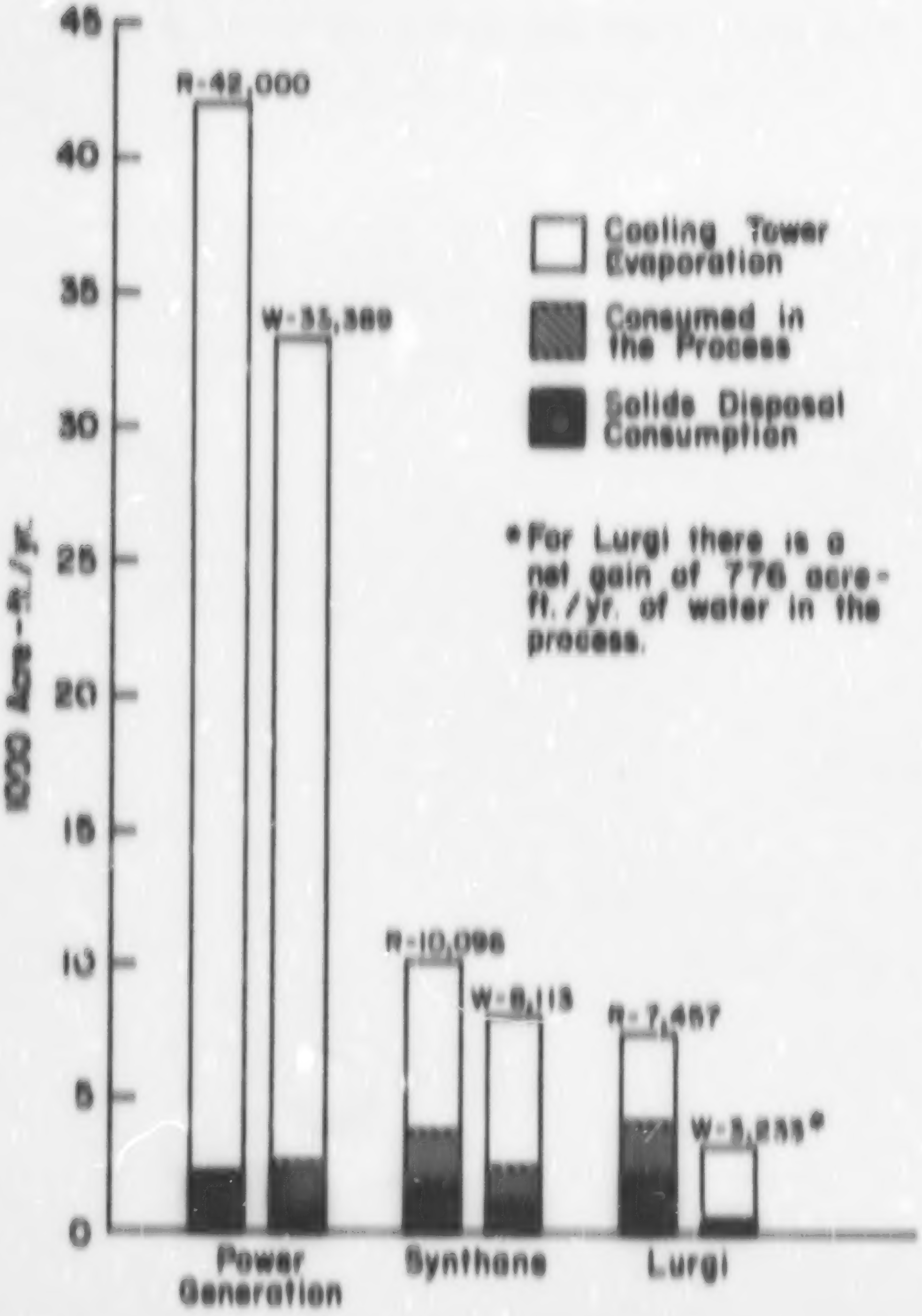

FIGURE 11-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE BEULAH SCENARIO

TABLE 11-16: WATER REQUIREMENTS FOR RECLAMATION

Mine	Acres Disturbed Per Year	Maximum Acres Under Irrigation	Water Requirement (acre-ft/yr)
Power Plant	840	4,200	3,150
Lurgi (2)	1,000	5,000	3,750
Synthane (2)	1,000	5,000	3,750
Total			10,650

comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

The water requirement associated with mining includes dust control, handling, crushing, and service as well as reclamation. Reclamation requirements have been calculated, assuming 5 years of irrigation at a rate of 9 inches per year, and are given in Table 11-16. Water to meet reclamation and dust control demands will come from mine dewatering activities whenever possible and will be supplemented with surface water if needed.

The first Lurgi facility, the power plant, and the two Synthane facilities will obtain their water through a pipeline from Lake Sakakawea because it is the largest, most reliable local source. Water will be withdrawn from an intake system below the minimum operating level of the lake and pumped to on-site reservoirs. The second Lurgi facility will use water released from Lake Sakakawea and withdrawn from its intake on the Missouri River downstream from Garrison Dam. As with the other facilities, the water will be pumped from the river to an on-site reservoir. Alternatively, the second Lurgi facility could use an upstream reservoir on the Knife River, such as the proposed Bronco Reservoir,[1] as a water source.

B. Municipal

As shown in Table 11-17, population increases associated with energy development will require additional water supplies. In the scenario area, municipal water use will total 4,645 acre-feet per year (acre-ft/yr) by the year 2000, with intermediate

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[1] Northern Great Plains Resources Program. *Water Work Group Report*. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974.

TABLE 11-17: WATER REQUIREMENTS FOR INCREASED POPULATION[a]
(acre-feet per year)

Town	1980	1985	1990	1995	2000
Beulah	133	371	119	483	147
Golden Valley	6	14	8	17	15
Hazen	78	162	106	400	190
Stanton	34	39	35	81	85
Zap	35	74	13	46	32
Center	73	39	39	60	81
Fort Clark	4	7	6	13	15
Hannover	15	3	3	7	8
Bismarck-Mandan	1,344	1,708	1,834	2,842	4,032
Mercer County/ Rural[b]	11	3	16	21	25
Oliver County/ Rural[b]	20	24	29	33	38

[a] Above 1975 base level; based on 125 gallons per capita per day.

[b] Based on 80 gallons per capita per day.

demands related to labor-intensive construction as high as 4,000 acre-ft/yr. Currently, water demands are being met with groundwater at all municipalities except Bismarck and Mandan, which use surface water from the Missouri River. Permits will be required from the North Dakota State Water Commission to withdraw any additional municipal water.

11.3.4 Effluents

A. Energy Facilities

The quantities of liquid wastes from the energy facilities hypothesized for the Beulah scenario are shown in Table 11-18. The largest effluent quantities are from flue gas desulfurization and ash disposal. Since the lignite in this area has only 6-percent ash, disposal requires less water than for coals with higher ash contents. The quantity of flue gas desulfurization effluent depends on the sulfur content of the coal (0.8 percent by weight on a dry basis) and the scrubber efficiency (80-percent removal assumed).

TABLE 11-28: RESIDUAL GENERATION FROM TECHNOLOGIES USED AT BEULAH[a]

	Stream Content[b]	Power Generation			Lurgi			Synthane		
		Wet-Solids (tpd)	Dry-Solids (tpd)	Water In Solids (gpm)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water In Solids (gpm)	Wet-Solids (tpd)	Dry-Solids (tpd)	Water In Solids (gpm)
Condensate Treatment Sludge	o	—	—	—	133	27	20	227	25	26
Boiler Demineralizer Waste	s	2.6	1.3	0.2	33	26	2	26	22	2
Treatment Waste	s	—	—	—	25	23	1.7	33	26	2.6
Treatment Waste	i	261	96	28	14	8	12	37	22	2
Flue Gas Desulfurization		5,354	2,228	551	457	244	40	380	78	29
Bottom Ash Disposal	i	594	788	19	2,610	2,031	101	972	462	23
Fly Ash Disposal	i	1,657	1,256	127	146	279	11	2,320	1,860	77
Total per plant		10,371	6,065	726	3,660	2,582	266	3,290	2,451	157
Total for Scenario		10,371	6,065	726	7,320	5,164	532	6,580	4,902	314

gpm = gallons per minute tpd = tons per day

[a] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Draft Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. Figures were adjusted to correspond to a load factor of 100 percent. See Appendix B.

[b] s = soluble inorganic
i = insoluble inorganic
o = insoluble organic

TABLE 11-19: EXPECTED INCREASES IN WASTEWATER FLOWS[a]

Town	1980	1985	1990	1995	2000
Beulah	0.10	0.27	0.09	0.34	0.11
Golden Valley	0	0.01	0.01	0.01	0.01
Hazen	0.06	0.12	0.08	0.29	0.14
Stanton	0.02	0.03	0.03	0.06	0.06
Zap	0.02	0.05	0.01	0.03	0.02
Center	0.04	0.03	0.03	0.04	0.06
Fort Clark	0	0.01	0	0.01	0.01
Hannover	0.01	0	0	0.01	0.01
Bismarck-Mandan	1	1.22	1.31	2.03	2.88

[a] Above 1975 base level, based on 100 gallons per capita per day.

All pollutant streams from the facilities will be discharged into clay lined, on-site evaporative holding ponds. Runoff prevention systems will be installed in all areas that have a pollutant potential. Runoff will be directed to either a holding pond or a water treatment facility.

B. Municipalities

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drain-fields), and urban populations will require waste treatment facilities. The wastewater generated by the population increases associated with energy development will amount to 1.25 million gallons per day (gpd) by 1980, 1.56 gpd by 1990, and 3.39 gpd by 2000 as shown on Table 11-19. During most of that time, the Bismarck-Mandan area will account for about 80 percent of the totals, but construction demand peaks will cause some fluctuations. Beulah will require an increase of 0.34 million gpd by 1995, more than double its average over the 25-year period under consideration. Similarly, Zap peaks in 1985 and Hazen in 1995. Current wastewater treatment practices in these communities are shown in Table 11-20.

Based on the current treatment facilities capacities, all the communities in the scenario will require new facilities to accommodate new population due to energy developments. In Bismarck-Mandan, facilities will not have to be expanded immediately but will need to be increased before 2000. New facilities must use "best practicable" waste treatment technologies to conform to 1983 standards and must allow for recycling or zero discharge of pollutants to meet 1985 goals. Policy issues concerning municipal sewage treatment are discussed in Section 14.3.4.

TABLE 11-20: WASTEWATER TREATMENT CHARACTERISTICS OF COMMUNITIES AFFECTED BY BEULAH SCENARIO

Town	Type of Treatment	Hydraulic Loading
Beulah	2-cell waste stabilization pond, 15 acres	at capacity
Golden Valley	3-cell waste stabilization pond, 5 acres	can expand by about 100-200 people
Hazen	2-cell waste stabilization pond, 18 acres	at capacity
Stanton	2-cell waste stabilization pond, 5.2 acres	at capacity
Zap	2-cell waste stabilization pond, 2.75 acres	at capacity
Center	waste stabilization, with new but presently inoperable system, 6.5 acres	old system--overloaded; new plus old system--at capacity
Fort Clark	no system	
Hannover	no system	
Bismarck	expanding to extended aeration, secondary clarifier, sand filtration, chlorination	designed for 55,000
Mandan	extended aeration, filtration, chlorination	designed for 20,000

Source: From telephone conversation with North Dakota Health Department.

11.3.5 Impacts

A. Impacts to 1980

The only activity scheduled before 1980 is the construction of the power plant, the first Lurgi gasification plant, and the openings of their respective lignite surface mines. The power plant will go on-line in 1980, but the Lurgi plant will not go into operation until 1985.

1. Surface Mines

The two coal mines to be opened before 1980 will have several potential impacts on local aquifers, but inasmuch as the mines will not be fully operational, these impacts will not be as great as in the next decade.

The chief groundwater effect of opening the mines will be the disruption of shallow bedrock aquifers in the Tongue River Formation. Both sandstone aquifers and lignite aquifers will be disturbed. Excavation of the box cut will disrupt the flow patterns of aquifers encountered, requiring mine dewatering which would lead to excessive drawdowns and aquifer depletion.

Although the two coal mines opened during this period will require water for dust control, revegetation will not begin until the next decade. Dust control requirements will be 400 acre-ft/yr at the mine for the power plant and 240 acre-ft/yr at the mine for the Lurgi plant. This water demand will be met by using trapped runoff and water from mine dewatering. No additional surface-water supplies will be required.

Runoff from the mine area will be high in suspended solids from erosion of open banks, spoil piles, and the mine floor and will contain higher than ambient concentrations of the trace metals associated with the coal. The greater part of the contaminated runoff will remain in or enter the mine area either by natural flow or through runoff retention structures. No contaminated runoff will be allowed to directly enter a natural stream. About 83 acre-ft/yr of runoff could be trapped by each 1,000 acres of active mine or reclamation area. If there is a large excess of water from mine dewatering and runoff, it will be treated and used as make-up for process water at the associated energy conversion facility.

2. Energy Conversion Facility

No significant impacts on aquifer systems are expected from energy conversion facilities because none of the facilities will be fully operational before 1980. If runoff is ponded during construction of the power plant or the Lurgi gasification plant, then shallow aquifers could be contaminated by infiltration from these ponds.

Construction activities at both the power plant and the Lurgi gasifier will remove vegetation and disturb the soil. Both of these activities will have an effect on surface-water quality by increasing the sediment load of local runoff. Additionally, the equipment used during construction will require maintenance areas and petroleum products storage facilities. Areas for the storage of other construction-related materials, such as aggregate for a concrete batch plant, will be required as well. All these facilities have the potential for contaminating runoff, but runoff control methods will be instituted at each one. Runoff will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water. Some of the water may be used for dust control.

The power plant construction will cause additional environmental effects where the water supply pipeline crosses the Knife River; construction activities will require that parts of the river be dammed temporarily. Increased silt loads and possible erosion of stream banks due to increased velocities at the dam site may result.[1]

3. Municipal Facilities

As shown on Table 11-17, the communities that grow as a result of the scenario energy facilities will require considerable additional quantities of water. These towns (with the exception of Bismarck and Mandan) are now taking their supplies from groundwater sources. This analysis assumes that the additional requirements will also be met from groundwater, which will be withdrawn by well fields in nearby alluvial aquifers. The productivity of the aquifers supplying each town should be sufficient to meet the needs of the respective towns without significant aquifer depletion. A possible exception is Hannover, which may have to be provided with supplemental water from surface sources or by a pipeline from a well or well field in the Square Creek aquifer.

As noted in Table 11-20, all the small towns in the scenario area, with the exception of Fort Clark and Hannover, presently use waste stabilization ponds for sewage treatment. Residences in Fort Clark and Hannover use individual septic tank and drainfield systems. Bismarck and Mandan have municipal sewage treatment plants. Both the stabilization ponds (because of leakage) and the septic tank systems may pose a water quality hazard to local shallow aquifer systems in both the bedrock and the alluvium. This hazard will be magnified by the population increases associated with the energy development projected for the scenario area.

The Bismarck-Mandan municipal complex is the only area that will have an increase in population related to energy development and that draws its municipal water supply from surface-water sources. However, increased withdrawals by Bismarck-Mandan to meet the projected population needs will not have an appreciable effect on the area's water source, the Missouri River.

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[1] Alternatively, the pipeline may be attached to the Highway 49 bridge that crosses the Knife River south of Beulah. Reconnaissance of the area would be necessary to determine if this alternative is viable.

B. Impacts to 1990

During the 1980-1990 interval, three of the energy facilities will begin operation. The power plant will go on-line in 1980, and the Lurgi plants will start operation in 1982 and 1987. The associated coal mines will begin operation concurrent with their plants.

1. Surface Mines

The three coal mines to begin operation during the 1980-1990 decade will have several impacts on groundwater quality and quantity. As the mines expand, larger areas of the shallow bedrock aquifers will be affected. Ultimately, a total of about 53,600 acres will be disturbed by surface mining for the power plant and the two Lurgi plants. Flow patterns will be disrupted in the aquifers, and if mine dewatering is necessary, the aquifers may be depleted locally. Aquifers in the lignite beds will be destroyed by the removal of the lignite, and aquifers in the overburden can not be restored to pre-mining conditions by replacement of the overburden during reclamation.

Depending on the chemical and mineralogical composition of the overburden, mining operations may result in the oxidation of materials that were formerly in reducing conditions. Such oxidation could cause the generation of acid waters and the release of dissolved contaminants which would infiltrate the substrate below and adjacent to the mines. The infiltrating contaminated water could in turn pollute local shallow bedrock aquifers.

These groundwater depletion and contamination problems will be manifested in local wells, springs, and seeps. Aquifer depletion will lower water levels in wells, and some wells may dry up or have to be deepened. Depletion may also cause flow reductions in springs, and some springs may dry up. Groundwater contamination from leaching of the overburden could ruin wells and/or springs. Most of the impacts will be on bedrock aquifers, but nearby alluvial aquifers could also be affected. These effects would be most pronounced where alluvial aquifers are recharged by base flow from bedrock aquifers. The streams associated with the alluvial aquifers may also receive contaminated water as base flow from bedrock or alluvial aquifers.

2. Energy Conversion Facility

The power plant and the two Lurgi gasification plants may have some impacts on local groundwater systems, but they will not contribute to local aquifer depletion because process and cooling water for these facilities will be provided from surface water sources. The runoff and effluents of the three plants will be similar in composition.

The power plant and the first Lurgi facility will draw water from Lake Sakakawea at a combined rate of about 49,500 acre-ft/yr. The second Lurgi facility will draw water from the Missouri River below Stanton at a rate of 7,450 acre-ft/yr. There will be no significant adverse environmental impacts from these withdrawals. Some increase in total dissolved solids will occur, although it is difficult to project the amount or effect of this increase.

Runoff must be controlled around all areas containing potential pollutants (including fuel tanks and coal storage piles) and sent to holding ponds for reuse or evaporation. Runoff will be increased during construction of the second Lurgi facility. The environmental effects will be similar to those previously stated for the construction of the first Lurgi facility.

The effluents from the energy conversion facilities likely to have the greatest impact on local groundwater supplies are those that will be ponded on the facility sites. Pond liners for the effluent storage ponds are designed to prevent leakage during the lifetime of the energy conversion facility, but they may leak because of failure, inadequate design, or improper maintenance. In the event of pond liner leakage, contaminants could enter the substrate either by direct infiltration of contaminated liquids or by leaching of solids or semisolids by natural precipitation. Local groundwater contamination may or may not occur, depending on the composition of the fluids or leachate and on the renovative capacity (filtration and absorption) of the substrate. This capacity will vary according to local geologic conditions.

The Lurgi facilities will produce solid wastes which will be trucked to disposal sites located in mined-out areas. Decomposition and leaching of these wastes could accentuate the contamination problems described earlier for the mines. In addition, there will be on-site ponds similar to those at the power plant for toxic, non-toxic, and sanitary wastes.

3. Municipal Facilities

As a result of population growth, municipal water requirements will increase dramatically about the mid-1980's and then will decrease to near the 1980 levels by the end of the decade. The alluvial aquifers or surface-water systems that supply the various communities should be able to meet these additional needs without aquifer depletion. Excessive groundwater withdrawals may occur at Beulah and Zap during the population peak, but the losses will be made up by recharge in later years.

C. Impacts to 2000

The two Synthane plants of the scenario will be constructed between 1990 and 2000. Both plants will be in operation by 2000.

1. Surface Mines

The three mines opened before 1990 will continue to have impacts during the 1990-2000 decade similar to the impacts described for the earlier decade. However, mining impacts will become more extensive as the mines increase in area and the two coal mines for the Synthane plants become operational.

The loss of water to local streams due to runoff impoundment will be as high as 5,800 acre-ft/yr. This loss could cause a significant change in the characteristics of the intermittent streams. The combined effects of mine dewatering and runoff loss could affect base flows as well as other stream characteristics in the perennial streams. These base flow effects could be significant.

2. Energy Conversion Facility

The construction activities at the Synthane plant will have effects similar to those described previously for the construction of other energy facilities.

The energy facilities will withdraw about 67,000 acre-ft/yr from Lake Sakakawea and about 7,450 acre-ft/yr from the Missouri River. These withdrawals may cause some increase in downstream pollutant concentrations because of the loss of higher quality water for dilution. This effect is difficult to evaluate quantitatively.

The effluents generated by the power plant and the two Lurgi gasification plants will continue to be produced during this decade. Additional effluents with similar impacts will be generated by the Synthane plant that will begin operating in 1995. If solid wastes from the Synthane plant are disposed of in the overburden material during reclamation of the mine, then the contaminating effects of the overburden described earlier for the mine will be accentuated.

The effluents from the Synthane plant will be handled onsite in a manner similar to that previously described for the Lurgi facilities. Because of the provisions of Public Law 92-500, there will be no planned continuous or intermittent discharge of pollutants to surface waters.

3. Municipal Facilities

As in the previous decade, population levels in the communities of the scenario area during the 1990-2000 decade will increase to a high level in the mid-1990's, then decrease toward the end of the decade. The aquifers and rivers used by all the communities except Beulah should be able to meet the increased water needs without significant aquifer depletion. At Beulah, the groundwater withdrawals may exceed the recharge to the Knife River aquifer temporarily, but the losses would be made up after the population declines.

The mid-decade population peak will again increase the stress on the quality of water in local shallow aquifers because of excess septic tank usage and leakage from waste stabilization ponds. The renovative capacity of the substrate is not unlimited, and continued introduction of septic tank and stabilization pond effluent will probably lead eventually to aquifer contamination.

D. Impacts after 2000

The second Synthane plant will begin operating in 2000. Most of the impacts after 2000 will occur after the various energy facilities shut down.

1. Coal Mine

The mines associated with the five energy conversion facilities will continue to produce the same impacts described for earlier decades as long as the plants operate. After the plants are shut down, the total mine area will be reclaimed and mine dewatering will cease. Although aquifer depletion will no longer be a concern, groundwater quality impacts will continue after the mine areas are reclaimed. However, over the long term, the oxidation and release of contaminants in the overburden will be completed, and the rate of release will taper off.

2. Energy Conversion Facility

The impacts on groundwater systems described for the energy facilities in earlier decades will continue as long as the facilities operate. The commencement of operations at the final Synthane plant in 2000 will increase the impacts mentioned earlier for the other Synthane plant. When all plants are operating, there will be a total water requirement of as much as 77,000 acre-ft/yr. This withdrawal will be entirely from the Missouri River system but should not have a significant effect on water availability. Some downstream increase in total dissolved solids will be evident as a result of the withdrawals.

After the facilities are decommissioned, the runoff control systems will no longer be operating. The amount of runoff contamination will be the result of erosion of the berms and leakage in the pond liners from lack of maintenance.

3. Municipal Facilities

Some of the people who migrate into the area because of energy development are likely to remain after the plants are shut down. If so, water supply demands on the alluvial aquifers and the Missouri River will continue. These sources should be able to meet the needs without significant depletion.

Communities that have not built municipal sewage treatment plants will continue to present a water quality hazard to local aquifers through the use of septic tanks and waste stabilization ponds. As noted earlier, this hazard is cumulative in that the renovative capacity of the substrate will eventually be exhausted.

By the end of the decade, wastewater treatment demands in communities with severe treatment problems should have decreased to levels within the plant capacities of the various communities.

11.3.6 Summary of Water Impacts

The coal mines for the scenario energy facilities will probably have several impacts on both groundwater and surface water. If the mine dewatering is necessary, local shallow bedrock aquifers in the Tongue River formation may be depleted. The result would be to lower water levels in wells or the drying up of wells, seeps, and springs. Additionally, bedrock recharge to alluvial aquifers and base flow to streams may be greatly reduced or eliminated. The water requirements at the mines will mostly be met from dewatering operations and should not place further demands on external sources.

Returning overburden to the mines during reclamation will also have several impacts on groundwater and surface water because overturning the overburden during mining operations will have changed its aquifer characteristics and infiltration rates. A total of about 84,400 acres will be mined and will experience increases in infiltration rates. The resulting loss of runoff to surface streams will amount to about 7,000 acre-ft/yr, and the runoff will have a higher sediment and dissolved solids content than before mining.

Overturning the overburden will also bring to the surface materials that were formerly deeply buried. Oxidation and release of these materials could lower the quality of surface water and groundwater systems. Infiltrating precipitation may leach these materials and carry them directly as recharge to aquifers or indirectly to surface-water sources either as springs or as base flow to streams. The potential pollution problem associated with the overburden will continue for several years after plant shutdown and will diminish slowly as oxidation and other reactions in the overburden go to completion.

During construction, the energy facilities may lower the quality (by increases in turbidity and dissolved solids content) of surface water because of soil disturbance. Accidental spills of fuels and lubricants may also enter the surface water system and infiltrate to groundwater systems.

The Missouri River is expected to be able to meet the water supply requirements (a maximum total of about 77,000 acre-ft/yr) of the facilities without appreciable impact on water availability or the environment.

The disposal of effluents from the energy conversion facility will likely have greater impacts on groundwater than on surface-water systems. The objective of zero discharge of pollutants set forth in the Federal Water Pollution Control Act (FWPCA)[1] will necessitate on-site entrapment and disposal of all effluents. The surface-water system will therefore be protected (at least for the life of the plants), but groundwater quality may be reduced by leakage and leaching of the disposed ponds and pits.

Disposal of urban sanitary wastes may pose several hazards to groundwater quality, and overloaded waste stabilization ponds may lower the quality of surface water. Two cycles of rapid population increases followed by rapid decreases, coupled with the requirements of the FWPCA, will tax the ability of the communities to provide adequate municipal treatment. Special measures may have to be instituted, such as using the municipal effluent as process water at one or more of the energy conversion facilities, to prevent the municipal effluent from degrading surface-water quality. The alternative is building expensive treatment plants that will not be used efficiently over the long term.

The identification and description of several water impacts have been limited by available information. Missing data include detailed information about process streams (needed to identify the composition of discharges to settling ponds) and about the rate of movement of toxic materials through pond liners (needed to estimate the portions that might reach shallow aquifers). More quantitative information will be sought during the remainder of the project so that these potential impacts can be properly evaluated.

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[1] Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

11.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

11.4.1 Introduction

The hypothesized developments in the Beulah scenario will occur in three counties of west-central North Dakota: Mercer, Oliver, and McLean. Of the five facilities, three will be in Mercer County; Oliver and McLean Counties will contain one facility each. Most of the anticipated social, economic, and political impacts can be attributed either directly or indirectly to the attendant population increases. This analysis focuses on Mercer County because the facilities are centrally located around Beulah and because the county has several other small towns which will be affected by the hypothetical developments.

11.4.2 Existing Conditions

Together, the three counties cover 6,117 square miles and had a 1974 population of 19,757 (a population density of 3.2 persons per square mile). Mercer County alone encompasses 1,042 square miles and had a 1974 population of 6,400 (about six persons per square mile). The area is served by several state highways and two railroads: the Burlington Northern running east and west, and the Milwaukee, St. Paul, and Sault Ste. Marie (Soo Line) running north and south.

Between 1950 and 1970, Mercer County's population decreased by 29 percent. The state's population also decreased over this period, but its 1 percent change was minor compared to the loss in Mercer County (Table 11-21). This decline continued at a slower pace into the early 1970's; the county population decreased 6.5 percent (from 6,600 to 6,175) between 1967 and 1972.

TABLE 11-21: POPULATION, MERCER COUNTY AND NORTH DAKOTA, 1950-1970

	Population			Percent Population Change		
	1950	1960	1970	1950-60	1960-70	1950-70
Mercer County	8,686	6,805	6,175	-21.7	-10	-29
North Dakota	619,636	632,446	617,761	+ 2.1	- 2.3	- 1

Source: U.S., Department of Commerce, Bureau of the Census. 1950 Census of Population; 1960 Census of Population; and 1970 Census of Population. Washington, D.C.: Government Printing Office, various dates.

There are six population centers in Mercer County, ranging from 100 to 1,200 people each. In addition to Beulah, incorporated towns in the county are: Stanton (the county seat), Golden Valley, Hazen, Pick City, and Zap. Unlike the county trend, population in the three largest towns (Beulah, Stanton, and Hazen) has remained fairly stable over the past 20 years. The major loss has been from the unincorporated rural areas.

Agriculture dominates the economy of Mercer County. In 1970, 33 percent of the laborforce was employed in agriculture, (more than 10 times the national average) as compared to 21 percent statewide. The rest of the laborforce was scattered throughout industry, with no other predominating sector (Table 11-22). However, the dominance of agriculture is on the decline in Mercer County, reflecting a statewide trend. Total cropland, land in farms, and the number of farms have all declined from

TABLE 11-22: EMPLOYMENT BY INDUSTRY GROUP IN MERCER COUNTY, 1970

Industry Group	Number Employed	Percent of Total
Agriculture, forestry and fisheries	713	33.4
Mining	115	5.9
Construction and manufacturing (Total)	151	7.1
Food and kindred products	6	0.3
Printing, publishing and products	3	0.1
Transporation, communication	70	3.3
Utilities and sanitary sewers	175	8.2
Retail Trade	210	10.5
Food and dairy product stores	69	3.4
Restaurants	49	2.4
Trade	210	9.8
Finance, insurance, and real estate	71	3.3
Miscellaneous services	388	18.2
Public administration	91	4.3
Total Employment	2,005	100

Source: U.S., Department of Commerce, Bureau of the Census, Census of Population: 1970; General Social and Economic Characteristics. Washington, D.C.: Government Printing Office, 1971.

1969 to 1974 in both Mercer and Oliver Counties.[1] Mining and utilities sectors now generate more income than any other sector except agriculture.[2] Both trends largely reflect the coal resource developments already under way in the area.

Both legislative and administrative functions in Mercer County are exercised by the Board of County Commissioners which is composed of three members serving 4-year terms. The Mercer County Planning Commission, consisting of nine members, serves under the County Board. The Commission's primary responsibilities consist of planning and zoning activities in all unincorporated areas of the county. Decisions of the Planning Commission are subject to approval by the County Commissioners.

In 1967, the majority of local government expenditures (60.3 percent) in the county went into education. Other major expenditures included: highways, 19.4 percent; public welfare, 3.8 percent; and health and hospitals, 0.4 percent. The total local expenditure for that year was $1.8 million. Law enforcement in Mercer County is handled by a sheriff and five deputies. The county is served by one hospital, located in Hazen, which has 39 beds and two full-time doctors. The county also provides a public health nurse who travels throughout the county.

Although Stanton is the county seat, almost all the retail and professional services are provided by the two largest towns, Beulah and Hazen.

Beulah is governed by a six-member city council and a mayor. There is no full-time planner; the city engineer performs planning services for the town when necessary. However, there is a planning commission which meets once a month, and the town has a master plan and a zoning code. Medical services consist of a clinic staffed by one doctor and one dentist, an eye clinic, and an ambulance service. Law enforcement is provided by one policeman and one county sheriff's deputy. The fire department consists of a 58-man volunteer force and two fire trucks. In addition, the city owns and operates its own water and sewage treatment system.

Hazen is governed by a mayor and four councilmen. The new position of city planner was created to deal with growth from energy development. It is now filled on a part-time basis by the city manager, but there are plans to fund it on a full-time basis starting in 1977. There is also a voluntary planning commission composed of nine members who meet twice a month. Law enforcement is provided by one policeman and one county sheriff's deputy. Fire protection is provided by a volunteer fire department. The city owns and operates its own water and sewer systems, which are presently operating at full capacity.

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[1] U.S., Department of Commerce, Bureau of the Census. *1974 Census of Agriculture: Preliminary Reports, Mercer County and Oliver County, North Dakota*. Washington, D.C.: Government Printing Office, 1976.

[2] U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." *Survey of Current Business*, Vol. 54 (May 1974, Part II), pp. 1-75.

Both Beulah and Hazen appear to have adequate physical capacity in their public service institutions to provide for the needs of their current residents. Further, both cities showed budget surpluses in fiscal 1973.[1] However, the pressures created by rapid growth could require rapid expansion of facilities and services in these communities, and thus a sudden increase in their public service employment. Under existing legislation, the cities are not prepared to do this; the maximum indebtedness of North Dakota cities cannot, by law, exceed 5 percent of their total assessed valuations. Thus, Beulah and Hazen are authorized debts of only $87,600 and $56,400, respectively. Given today's costs, such sums will not allow much expansion of public services in these communities. Further, even if a referendum should pass by a vote of two-thirds of the local residents, this limit can only be raised an additional 3 percent.

11.4.3 Population Impacts

Most of the social, economic, and political impacts in the Beulah scenario will result from population increases, initially during construction and later during operation of the facilities.

The initial major effect of the Beulah area will be caused by construction of the electric generating plant beginning in 1975, followed in 1977 by work on the first Lurgi gasification plant. The construction employment results in the sharply cyclical employment pattern of Table 11-23 (based on the employment multipliers in Table 11-24). Construction work in this scenario extends throughout the 1975-2000 time period, with the brief exception of 1988 and 1989. The entire employment-induced population change is assumed to occur within the existing towns and is allocated among those in Mercer, Oliver, and McLean Counties

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[1] This is typical of North Dakota's recent experience. The state general fund has a surplus equal to almost a full year's budget, and voters recently approved a reduction in sales tax rates. See the Denver Post, November 6, 1976.

TABLE 11-23: CONSTRUCTION AND OPERATION EMPLOYMENT IN BEULAH ENERGY DEVELOPMENT SCENARIO, 1975-2000

Year	Construction	Operation	Total
1975	520	0	520
1976	2,560	0	2,560
1977	2,630	110	2,740
1978	2,870	630	3,500
1979	3,050	660	3,710
1980	3,600	1,570	5,170
1981	4,830	2,160	6,990
1982	2,690	2,410	5,100
1983	190	2,410	2,600
1984	790	2,400	3,190
1985	2,880	2,650	5,530
1986	4,830	3,240	8,070
1987	2,660	3,490	6,150
1988	0	3,490	3,490
1989	0	3,490	3,490
1990	30	3,490	3,520
1991	190	3,490	3,680
1992	790	3,490	4,280
1993	2,880	3,740	6,620
1994	4,830	4,330	9,160
1995	2,660	4,580	7,240
1996	190	4,580	4,770
1997	790	4,580	5,370
1998	2,880	4,830	7,710
1999	4,830	5,410	10,240
2000	2,600	5,660	8,260

Source: Carasso, M., *et al.* *The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 11-24: EMPLOYMENT AND POPULATION MULTIPLIERS IN THE BEULAH SCENARIO

Year	Service/Basic Employment Multipliers[a]	
	Operation	Construction
1975-1979	0.5	0.3
1980-1984	0.7	0.5
1985-1989	1.0	0.7
1990-2000	1.3	0.7
Activity	**Population/Employee Multipliers[b]**	
Construction	2.0b	
Operation	2.5	
Service	2.3	

[a] These values were selected after examining several studies concerning energy development in North Dakota and the Northern Great Plains, including Leholm, A., F.L. Leistritz, and J.S. Wieland. Profile of North Dakota's Coal Mine and Electric Power Plant Operating Work Force, Agricultural Economics Report No. 100. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; University of Denver, Research Institute. The Social, Economic, and Land Use Impacts of a Fort Union Coal Processing Complex, Final Report, for U.S., Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975. PB-1526; Luken, Ralph A. Economic and Social Impacts of Coal Development in the 1970's for Mercer County, North Dakota. Washington, D.C.: Old West Regional Commission, 1974; Dalsted, Norman L., et al. Economic Impact of Alternative Energy Development Patterns in North Dakota, for Northern Great Plains Resources Program. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1974; Argonne National Laboratory, Energy and Environmental Systems Division. Mercer County Case Study: The Economic Impacts, Draft Report. Argonne, Ill.: Argonne National Laboratory, 1976; See Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976, pp. 54-59 for a discussion of low multiplier effects in rural areas.

[b] Adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976. These multipliers represent aggregates of married couples with children, working wives, and single employees, not simply family sizes.

as well as the Bismarck-Mandan area.[1] The population estimates are shown in Table 11-25 and Figures 11-5 and 11-6.

Because of construction period peaks and the location of the plants in this scenario, Mercer County is expected to nearly double in population by 1985, fall to around 8,600 in 1990, rise to 14,000 in the mid-1990's, then level off at just over 10,000 by the end of the century. Beulah and Hazen, the largest towns in the county, will closely reflect this trend. The early scenario activity will take place in Oliver County, where the total population will increase rapidly until 1980, then gradually decrease, ending with a population of about 3,350 by 2000. Much of the energy development activity in Oliver County will focus on the town of Center, which is expected to double in population to 1,200. The population of McLean County, the site of the last scenario gasification facility, will increase by nearly 3,000 people after 1995. This increase will be concentrated in the town of Underwood, which will grow by nearly a factor of 5 between 1975 and 2000. Finally, the Bismarck-Mandan urban area to the southeast should grow steadily to 75,700 (a 61-percent increase) over the period. The largest absolute population growth from the scenario is expected to occur in Bismarck and Mandan.

Age-sex breakdowns of the projected population in Mercer County allow estimates of housing and educational needs. Since most of the Beulah scenario developments will be located in Mercer County, the effects of the construction population booms on that county are of particular interest. The 1970 age-sex distributions and data from community surveys in the West were used to estimate age-sex distributions for new employees and their families.[2] The resulting distribution for Mercer County shows the effects of construction activity. During heavy construction periods (e.g., 1985 and 1995 in Table 11-26), the 20-34 age groups, particularly males, are predominant. However, other age groups, also appear to vary in relation to the amount of energy construction.

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[1] Population changes were estimated by means of the economic base model (See Part II, Introduction) and the multipliers in Table 11-28. The overall estimates were allocated among those towns in the Beulah area within an hour's drive of each facility. The allocation model assumes that larger towns and closer towns should attract a greater proportion of new residents and balances the effects of population and commuting distance.

[2] Mountain West Research, *Construction Worker Profile*, Final Report, Washington, D.C.: Old West Regional Commission, 1976.

TABLE 11-25: POPULATION ESTIMATES FOR THE BEULAH SCENARIO AREA, 1975-2000[a]

Location	1975	1980	1985	1990	1995	2000
Mercer County						
Beulah	1,350	2,300	4,000	2,200	4,800	2,400
Gold Valley	100	140	200	160	220	210
Hazen	1,240	1,600	2,400	1,000	4,100	2,600
Stanton	520	760	900	770	1,100	1,130
Zap	270	450	800	360	600	500
Rural	2,920	2,900	3,950	3,100	3,150	3,200
Total	6,400	8,150	11,250	8,670	14,000	10,050
Oliver County						
Center	620	1,050	900	900	1,050	1,200
Ft. Clark	100	130	150	140	190	210
Hannover	100	210	120	120	130	160
Rural	1,380	1,600	1,650	1,700	1,750	1,800
Total	2,200	2,950	2,800	2,850	3,150	3,350
McLean County						
Big Bend	100	125	140	140	170	240
Riverdale	700	900	1,000	1,000	950	1,300
Underwood	780	975	1,000	1,050	1,200	3,500
Washburn	800	1,100	1,100	1,100	1,350	1,900
Other	9,120	9,300	9,700	10,100	10,300	10,600
Total	11,500	12,400	13,000	13,300	14,000	17,500
Bismarck-Mandan County						
Total	46,900	56,500	59,100	60,000	67,200	75,700

[a] Natural increases of 0.8 percent through 1980 and 0.5 percent thereafter are included. Estimated population declines in this table assume that construction workers and their families will leave the area when construction employment does not carry over from year to year. Given the large amount of energy construction activity which might occur in the West, this assumption is as reasonable as its alternatives. Totals are rounded.

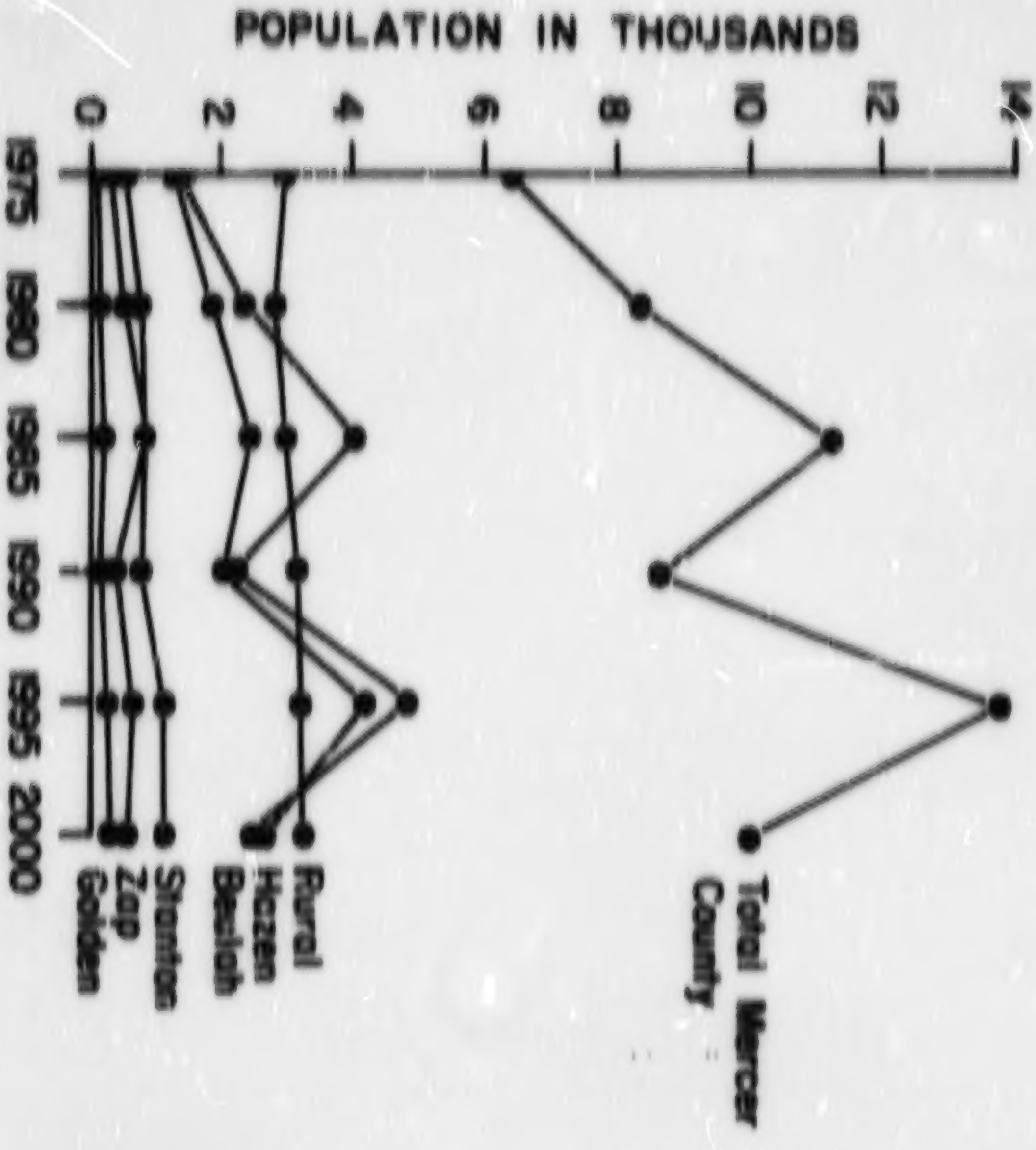

FIGURE 11-5: POPULATION ESTIMATES FOR BEULAH SCENARIO AREA, 1975-2000

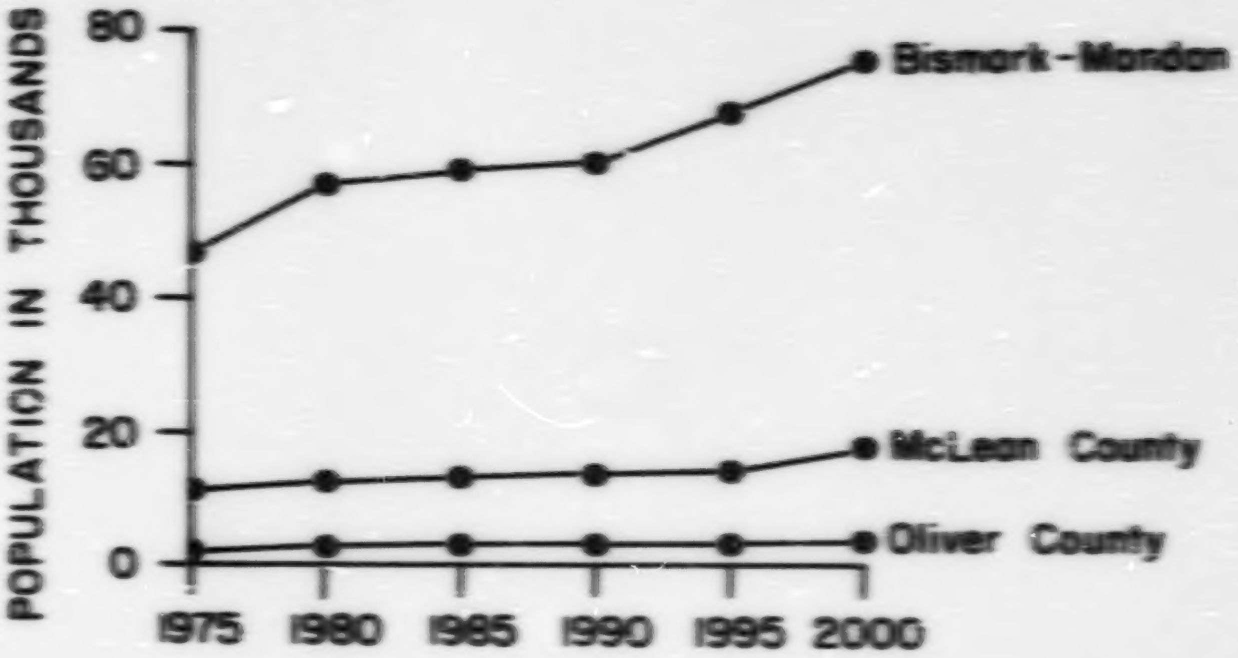

FIGURE 11-6: POPULATION ESTIMATES FOR OLIVER AND MC LEAN COUNTIES AND BISMARCK-MANDAN, 1980-2000

TABLE 11-26: PROJECTED AGE-SEX DISTRIBUTION FOR MERCER COUNTY, 1975-2000[a]

Age	1975	1980	1985	1990	1995	2000
Female						
65-Over	.057	.032	.020	.036	.018	.024
55-64	.061	.040	.033	.059	.035	.068
35-54	.115	.105	.121	.180	.133	.204
25-34	.051	.110	.130	.072	.131	.066
20-24	.027	.042	.047	.018	.041	.015
17-19	.020	.022	.023	.012	.019	.012
14-16	.035	.024	.019	.031	.020	.025
6-13	.091	.067	.055	.061	.050	.050
0-5	.050	.044	.026	.016	.025	.017
Total	.507	.486	.474	.485	.472	.481
Male						
65-Over	.051	.029	.021	.038	.020	.027
55-64	.065	.044	.037	.067	.041	.079
35-54	.118	.116	.140	.206	.155	.235
25-34	.054	.128	.152	.077	.153	.067
20-24	.019	.044	.054	.011	.044	.009
17-19	.023	.025	.023	.008	.019	.010
14-16	.030	.021	.019	.032	.020	.025
6-13	.083	.063	.054	.061	.050	.050
0-5	.050	.044	.026	.016	.025	.017
Total	.493	.514	.526	.516	.527	.519

Source: Table 11-28 and Mountain West Research, _Construction Worker Profile_, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[a] Totals do not always sum to 1.0 because of rounding.

TABLE 11-27: NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN MERCER COUNTY 1975-2000

Year	Number of Households[a]	Number of Elementary School Children[b]	Number of Secondary School Children[c]
1975	1,950[d]	1,100[d]	400[d]
1980	3,000	1,400	480
1985	4,500	1,500	540
1990	3,400	1,300	540
1995	5,700	1,750	690
2000	4,200	1,250	620

[a] Includes single-person households, which are about 20 percent of the total.

[b] Ages 5-13 plus 25-percent adjustment to improve estimates.

[c] Ages 14-16 plus 25-percent adjustment to improve estimates.

[d] Estimated.

11.4.4 Housing and School Impacts

Housing demand in the Mercer County area will be highly dependent on construction activity. The number of households in the county will reach a peak of 5,700 in 1995 but will level off to 4,200 in 2000; this compares to a 1975 level of 1,950 households (Table 11-27, Figure 11-7). The peak housing demands will be met largely by mobile homes, as is common in short-term situations. These homes will be located mainly in and around Beulah, the town most affected by the cyclical changes in population. If housing construction in the county keeps up with the projected needs, over 1,200 single-family and 500 multi-family units will be built by the year 2000 (Table 11-28). Currently, about 12 percent of the county's housing consists of mobile

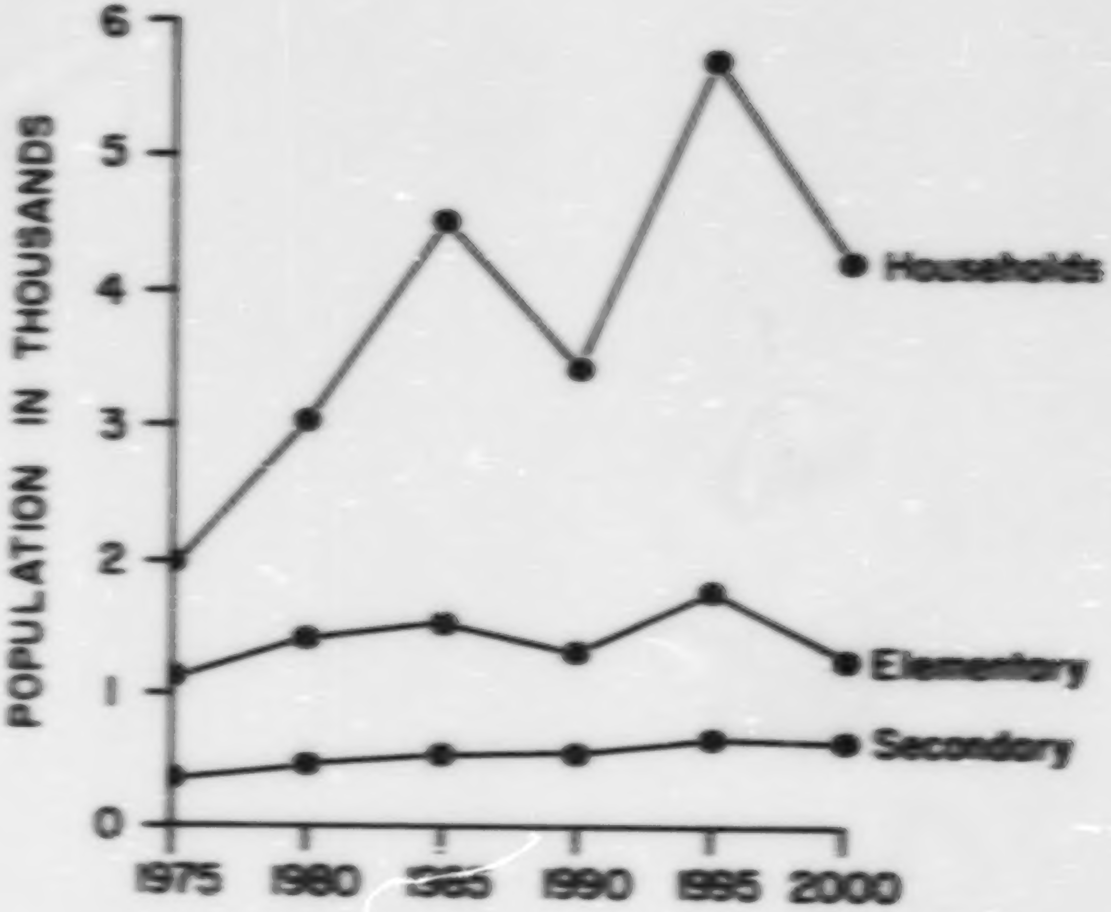

FIGURE 11-7: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY, AND SECONDARY SCHOOL CHILDREN IN MERCER COUNTY, 1975-2000.

TABLE 11-28: DISTRIBUTION OF NEW HOUSING NEEDS BY TYPE OF DWELLING[a]

Period	Mobile Home	Single-Family	Multi-Family	Other[b]
1975-1980	420	410	130	90
1980-1985	580	610	180	120
1985-1990[c]	-890	0	0	-210
1990-1995	850	190	250	300
1995-2000[c]	-860	0	-140	-300

[a] Compiled from Table 11-31 and data adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 103.

[b] For example, campers and recreational vehicles.

[c] Negative values indicate dwelling removal, under the assumption that mobile homes will be the first to be removed during periods of population decline.

homes,[1] a proportion that would more than triple in such peak construction years as 1985 and 1995.

School enrollment impacts show another trend, with differences in timing between elementary and high schools (Table 11-27). The overall peak will be reached in 1995, when over 2,400 students will be enrolled (72 percent in elementary schools). In terms of the school financial situation, the current surplus of 30 classrooms would allow any need through 1990 to be met with current facilities (Table 11-29). A short-term need for 15 additional classrooms in 1986 and in the 1990's suggests that low-cost temporary classrooms or double sessions could largely solve the demand problem without building any new, permanent schools. Annual operating expenditures for schools in Mercer County should be almost double the present $1.5 million level during the 1990's; however, the average annual budget during the scenario period should be less than 50 percent above current expenditures. The Bismarck-Mandan school districts will

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[1] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

TABLE 11-29: SCHOOL FINANCE NEEDS FOR MERCER COUNTY AND BISMARCK-MANDAN, 1975-2000

County	Year	Enrollment Increase Over 1975	Classrooms at 21 Students Per Room[a]	New Capital Expenditures (in millions of dollars)[b]	New Operating Expenditures (in millions of dollars)[c]
Mercer	1975	1,500	102[d] (71)		
	1980	380	101 (89)	0.0	1.49
	1985	540	101 (97)	0.0	0.70
	1990	340	101 (87)	0.0	1.88
	1995	940	116	0.84	1.22
	2000	370	101 (90)	0.0	0.48
Bismarck-Mandan	1975	12,300	457[d]		
	1980	2,100	507	5.25	2.73
	1985	2,640	531	6.50	2.38
	1990	2,800	540	7.00	2.64
	1995	4,100	600	10.25	4.35
	2000	5,700	676	14.25	6.43

[a] Numbers in parentheses are classroom needs, which are at times less than the 101 currently available.

[b] Assuming an average of $2,500 per pupil space. See Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81. Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971. Data from that source were inflated to 1975 dollars.

[c] Assuming $1,300 per pupil: see Argonne National Laboratory, Energy and Environmental Systems Division. Mercer County Case Study: The Economic Impacts. Draft Report. Argonne, Ill.: Argonne National Laboratory, 1976, Appendix A. An overall average of about $1,000 per pupil was inflated to 1975 dollars.

[d] Actual number in 1974 from Mountain Plains Federal Regional Council, Socio-economic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

have to build over 200 classrooms, at a cost of over $14 million, because those districts are already operating near their capacities.

11.4.5 Land-Use Impacts

Nearly 50 percent of Mercer, Oliver, and McLean Counties is currently cropland. The land occupied by energy facilities will occupy about 140 square miles (360 square kilometers) or about 3.7 percent of the land in the three counties. Most of this land will be used for surface coal mining on existing farms which have already been leased to energy developers.[1] In fact, the total amount of mined land at any point in the scenario might be somewhat less as land is returned to farmers through reclamation. Additional urban development should occupy only about 6 square miles; few, if any, new roads will be needed, though a number of old roads may be upgraded.

11.4.6 Economic and Fiscal Impacts

A. Economic

The economy of the Beulah area is still predominantly agricultural, particularly Oliver County where 58.8 percent of 1972 personal income was derived from agriculture. The 1972 levels for McLean and Mercer Counties were 42.0 percent and 27.2 percent, respectively. In that year, the mining, construction, and utility industries were already important to Mercer County, providing 30 percent of personal income for its inhabitants.[2] As energy developments increase in the area, additional lands will be taken out of agricultural production, but employment opportunities in energy-related sectors will expand. Consequently, the Mercer County economy should become even more energy dependent, and the other counties will also see a percentage decline in their reliance on agriculture.

Largely because of the change in industry mix areawide, the income distribution will rise to reflect the higher paying

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[1] Johnson, Jerome E., Robert E. Beck, and Cameron D. Sillers. The North Dakota Farmer/Rancher Looks at Severed Mineral Rights. Agricultural Economics Miscellaneous Report No. 18. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975.

[2] U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 11-30: PROJECTED INCOME DISTRIBUTION FOR MERCER COUNTY, 1975-2000 (in 1975 dollars)

Income	1975[a]	1980	1985	1990	1995	2000
Less than $4,000	.188	.105	.074	.097	.056	.082
4,000- 5,999	.122	.071	.054	.067	.049	.058
6,000- 7,999	.114	.065	.045	.061	.042	.052
8,000- 9,999	.087	.073	.063	.075	.066	.075
10,000-11,999	.086	.089	.092	.096	.095	.097
12,000-14,999	.110	.117	.119	.140	.130	.136
15,000-24,999	.234	.381	.434	.389	.439	.407
25,000-over	.061	.100	.119	.096	.112	.093
Median Household	9,700	14,500	16,300	14,300	16,200	15,000

Source: Tables 11-24, 11-25, and 11-26 and Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[a] U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's Cities and Counties: 1970. Washington, D.C.: Government Printing Office, 1973.

employment opportunities for both local residents and newcomers.[1] For example, in Mercer County the highest incomes will occur during the 1985 and 1995 construction booms, when nonlocals will be a large part of the laborforce (Table 11-30). A projected overall rise of over 50 percent in median income by 2000 includes the expansion of the local economy and employment of local people as well as immigrants to the area.

The increases in the service sector will be concentrated in local retailing activities, particularly in Beulah. Beulah, Hazen, Underwood, and Washburn currently serve as local trade centers, whereas Mandan and Bismarck are the regional centers for wholesale and retail activity.[2] The primary change expected from energy development is a growing predominance of Beulah in the Mercer-Oliver-McLean County area. Because of the attraction of

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[1] In recent years, high agricultural prices have resulted in high farm incomes, often exceeding the projected energy operation salaries. Over the long term, however, energy occupations will be higher paying.

[2] Owens, Wayne W., and Elmer C. Vangsness. Trade Areas in North Dakota. Extension Bulletin No. 20. Fargo, N.D.: North Dakota State University, Cooperative Extension Service, 1973.

Bismarck and Mandan, no major secondary industries are expected to locate near Beulah.

Mercer County communities must provide public services for the increased population. Beulah and Hazen, in particular, will require extensive additions to their water and sewage treatment facilities through 1985 (Table 11-31).[1] Facilities capable of meeting the 1985 demands should be adequate through 2000, except for the 1995 construction boom. The Bismarck-Mandan area also will have an early capital need (before 1980) for over $22 million, which will become somewhat more gradual for the rest of the period. Other capital needs, especially for health care facilities, will demand considerable expenditures, as indicated in Table 11-31.

In terms of operating expenditures, Beulah's municipal budget should triple to nearly $600,000 during the peak construction years. Hazen will be affected much the same as Beulah in absolute terms, which means a much greater proportional growth (Table 11-32). Since energy developments will be located in rural areas and the associated population will settle in the towns, some revenues will not add directly to the tax base of impacted towns.

The temporary removal of land from agriculture, the availability of well-paying jobs, and the expansion of towns in the Beulah area will combine to change the region into a more diverse economy. The early boom will cause planning and budgetary difficulties for the towns nearby, although revenues should be sufficient for needs.[2] Most long-term benefits will accrue to the Bismarck-Mandan area, where wholesale and retail activity will expand to serve the increased population.

B. Fiscal

North Dakota has recently enacted significant changes in the collection and disbursement of taxes on energy facilities. The

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[1] Actually both towns have some unused capacity, so that early needs will be somewhat less. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. *Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII*. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2] Leistritz, F.L., A.G. Leholm, and T.A. Hertsgaard. "Public Sector Implications of a Coal Gasification Plant in Western North Dakota," in Clark, W.F., ed. *Proceedings of the Fort Union Coal Field Symposium*, Vol. 4: *Social Impacts Section*. Billings, Mont.: Eastern Montana College, 1975, pp. 429-41.

TABLE 11-31: PROJECTED NEW CAPITAL EXPENDITURES REQUIRED FOR PUBLIC SERVICES IN SELECTED NORTH DAKOTA COMMUNITIES, 1975-2000
(in thousands of 1975 dollars)

Public Services	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
Beulah					
Water and Sewage	1,670	2,990	0	1,408	0
Law Enforcement	17	30	0	14	0
Other	544	974	0	458	0
Hazen					
Water and Sewage	986	1,056	0	2,992	0
Law Enforcement	10	11	0	30	0
Other	321	344	0	974	0
Bismarck-Mandan					
Water and Sewage	16,900	4,580	1,584	12,670	14,960
Law Enforcement	170	46	16	128	150
Other	5,500	1,490	516	4,126	4,870

Source: Water and sewage plant requirements amount to $1,760,000 for each additional 1,000 population; $17,730 is required for law enforcement capital costs; and $573,000 goes for other physical plant needs, broken down as follows: parks and recreation (33 percent); hospital (46 percent); libraries (5 percent); fire protection (5 percent); administration (3 percent); and public works (8 percent). Streets and roads not included as municipal capital costs. See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All data from that source are inflated to 1975 dollars. See also Lindauer, R.L. Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

TABLE 11-32: NECESSARY OPERATING EXPENDITURES OF MUNICIPAL GOVERNMENTS IN SELECTED COMMUNITIES, 1980-2000[a]

Year	Beulah	Hazen	Bismarck-Mandan
1980	114,000	67,000	1,152,000
1985	318,000	139,000	1,464,000
1990	102,000	91,000	1,572,000
1995	414,000	343,000	2,436,000
2000	126,000	163,000	3,456,000
Current (1974) Budget[b]	143,850	10,950	12,417,206

[a] Based on a figure of $120 per capita, broken down as follows: highways (25 percent); health and hospitals (14 percent); police (7 percent); fire protection (12 percent); parks and recreation (6 percent); libraries (4 percent); administration (10 percent); sanitation and sewage (10 percent); and other (12 percent). See THK Associates, Inc., Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

[b] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

new severance tax applies to the mining of coal, while the new privilege tax applies to the conversion of coal to other energy forms. (Thus, operators will have some incentive to "strip and ship" and avoid the privilege tax, rather than process or use the coal at the mine site.)

The Beulah scenario envisions an annual production of 60.3 million tons of coal by the end of the century, a 3,000 megawatt-electric (MWe) power plant (full production by 1980), and four assorted gasification plants to come on-line between 1982 and 2000. Applying current tax rates to the projected incremental increases, revenues likely to arise from these energy developments are:

1. Coal Mining. The severance tax is $0.50 per ton.[1] The authorizing legislation makes explicit provision for keeping up with inflation; thus, the $0.50 figure can be used throughout, in terms of 1975 currency. With the production levels of this scenario, the severance tax yields the following revenues:[2]

1980	1985	1990	1995	2000	
$12.3	$17.8	$20.5	$25.3	$30.1	(millions)

2. Electrical Generation. The tax rate is one-fourth mill per kilowatt-hour. For a 3,000-MWe plant at 70-percent load factor, the tax would amount to $4.6 million per year. The assumptions are that one-fourth of this rate will be achieved in 1977-1978, one-half in 1979, and the full rate thereafter.

3. Gasification. Conversion facilities pay either 2.5 percent of gross receipts or $0.10 per thousand cubic feet, whichever is greater. Taking the $0.10 rate, each gasification facility will generate revenues of $8.2 million per year.

4. Property Taxes. Although the privilege tax stands in lieu of *ad valorem* taxes *on conversion facilities*, coal mines are still subject to property taxes. In North Dakota, the average current assessment ratio is 17 percent, the legal taxable value ratio is 50 percent, and the average mill levy is 174 (17.4 percent).[3] All these factors are effectively multiplied together to yield a true tax rate of 1.48 percent of market value.

   During the scenario time frame, five surface mines will be inaugurated at a total development cost of $493 million. Applying the 1.48-percent rate to these facilities, property tax revenues will grow as follows:

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[1] Bronder, Leonard D. *Taxation of Coal Mining: Review with Recommendations.* Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976; Stenehjem, Erik. Intra-Laboratory Memo. Argonne National Laboratory, February 9, 1976.

[2] Distribution will be considered after all revenues are listed.

[3] Stenhjem, Erik. Intra-Laboratory Memo.

1980	1985	1990	1995	2000	
$3.03	$4.38	$4.99	$6.14	$7.30	(millions)

5. Distribution. The new tax laws take cognizance of those jurisdictional problems occurring in other energy-rich areas. In most of the other scenarios, the county in which facilities are located has reaped the most significant portion of the revenues, while other jurisdictions have had to provide extra services without the benefit of new taxes. North Dakota has, instead, largely supplanted the property tax with new formulas designed to spread revenues over a variety of governmental units.

   The severance tax is distributed into the following shares:

   a. 35 percent to the Coal Development Impact Office (see Section 11.4.8).
   b. 30 percent to the state general fund.
   c. 5 percent to the county of origin.
   d. 30 percent to the state trust fund.

After legislative appropriation, the impact development office has wide latitude in disbursing these funds to any local units impacted by coal development. The trust fund, administered by the board of university and school lands, is to be held in perpetuity. However, income from this fund can be paid to the state general fund. The Beulah scenario should result in an accumulation of $133 million by the end of the century. An income of 5 percent, then, would make another $6.6 million available to the state beyond its 30-percent share.

The coal conversion tax is distributed as follows:

1. 90 percent to the state general fund.
2. 4.5 percent to the schools in originating county.
3. 4.0 percent to the county general fund.
4. 1.5 percent to the towns in the originating county.

School and town allocations must be prorated on the basis of attendance and population, respectively.

In recent years, Mercer County has been allocating 51 percent of tax revenues to the general fund, 48 percent to schools,

TABLE 11-33: ALLOCATION OF TAXES LEVIED DIRECTLY ON ENERGY FACILITIES, MERCER COUNTY
(millions of 1975 dollars)

Jurisdiction	1980	1985	1990	1995	2000
State General Fund[a]	8.1	18.2	28.1	38.6	49.4
Impact Development Office	4.3	6.2	7.2	8.9	10.5
County General Fund	2.3	3.6	4.3	5.6	6.7
School Districts	1.6	2.7	3.3	4.2	5.2
Towns	0.1	0.2	0.3	0.4	0.6
Total	16.4	30.9	43.2	57.7	72.4

[a] Including medical fund and income from trust fund (at 5 percent).

and 1 percent to a state medical fund.[1] This is assumed to continue.

These various taxes will be applied to the full complement of energy facilities (five mines, an electric station, and four gasification plants), and the revenues will be distributed by formula. The net result, by jurisdiction, is listed in Table 11-33.

These revenues appear adequate to yield an overall net surplus. However, the state government will capture most of this new revenue and will also benefit from income and sales taxes (not calculated here). In addition, the towns are only guaranteed $560,000 per year by the end of the century; their solvency depends on allocations from the Coal Development Impact Office (which operates within the office of the governor).[2] That source can cover all municipal fiscal impacts if allocated with that goal in mind. Local property taxes might even be reduced with no real decline in the ability to provide government services in the long term.

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[1] U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974.

[2] They may also benefit from commercial and residential property taxes and utility fees not calculated here.

11.4.7 Social and Cultural Impacts

The removal of land from agricultural production for strip mining will be difficult for some farmers, but the compensation from the mining activity, as well as the jobs made available, will be welcomed by many. The steady out-migration from the Beulah area in recent years would be turned around, an event that would also be favored by most residents.[1] Judging from recent experiences, a large part of the laborforce for energy development will be made up of local people.[2] Many other workers are likely to be those who have left North Dakota in the past and would like to return to the area. During construction, however, only up to 25-30 percent of the needed workers are likely to be North Dakotans, and at least one-third of all employees will be from outside the Northern Great Plains. Non-local employment of such skilled workers as pipefitters and electricians is even more likely, up to levels of 70 percent and higher.[3]

Major uncertainty exists concerning the extent to which the local housing construction industries will be able to supply single-family and multi-family homes. A shortage of homes and subsequent reliance on mobile homes would be unpleasant to many families arriving in the Beulah area. Medical care will also be a problem for the scenario area, where only four doctors are available between Mandan and Dickinson (70 miles southwest of Beulah), two of whom are affiliated with a 39-bed hospital at Hazen.[4] Government policy is generally unable to induce doctors to settle in small communities when there are ample opportunities in more attractive places,[1] although loan forgiveness programs have had some success.[2] For example, Underwood, Stanton, and Center currently have no doctors, and projected population growth will create the need for physicians in these towns. The Bismarck-Mandan area currently has 91 doctors but could need as many as 50 more by 2000. The urban area clearly will have much less difficulty attracting physicians than the rural towns.

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[1] Bickel, D., and C. Markell. "Problems and Solutions Related to Measuring Regional Attitudes Toward Coal Development and Life Styles in the Eastern Williston Basin," in Clark, W.F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 4: Social Impacts Section. Billings, Mont.: Eastern Montana College, 1975, pp. 421-28.

[2] Leholm, A., F.L. Leistritz, and J.S. Wieland. Profile of North Dakota's Coal Mine and Electric Power Plant Operating Work Force, Agricultural Economics Report No. 100. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975.

[3] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 14-19.

[4] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

11.4.8 Political and Governmental Impacts

The population increases expected in the Beulah scenario will create a general need for more local government resources. None of the towns in the area has a full-time mayor or city manager,[3] but the planning needs during the energy boom may provide sufficient impetus to change that. Zoning and subdivision regulations, building codes, and mobile home park design standards already exist to guide local expansion and permanent construction in municipalities.

A major uncertainty in the scenario area is the extent to which the local housing construction industry will be able to cope with increasing demand for single-family and multi-family homes. At present, North Dakota does not have an administrative organization at the state level to assist in the establishment and financing of necessary housing in rural areas; the state also does not have a housing financing agency or corporation whose specific purpose is to assist in securing mortgage money for traditional lending institutions. A program designed to administer bonds and related fiscal mechanisms could be made operational through the Bank of North Dakota, but the statutory authority usually granted to state housing finance corporations is lacking. Consequently, growth communities are unable to use many national and federal financial sources for housing that are available to other states.[1]

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[1] Lankford, Phillip L. "Physician Location Factors and Public Policy." Economic Geography, Vol. 50 (July 1974), pp. 244-55.

[2] Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

[3] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

Besides problems of housing, county and local governments will be hard-pressed to provide the range of services that traditionally falls within the scope of their responsibilities. Mitigation of negative impacts in facilities and services categories will depend largely on the availability of front-end capital and the ability of government to plan for such impacts. As noted in the fiscal analysis, existing debt ceilings in Beulah and Hazen are not adequate if these localities are to cope with projected demands. Consequently, the fiscal solvency of these two communities, as well as others in the scenario area, depends largely on the distribution of funds from the recently created Coal Development Impact Office. The Office administers the revenues collected from the state severance tax on coal. By statute, the Coal Development Impact Office has the authority to formulate a plan to provide financial aid to local governments in coal development areas and to make grants to counties, cities, school districts, and other taxing districts. Decisions regarding the amount of an impact grant awarded to an eligible political subdivision must consider the amount of revenues which the local governments will gain from other tax sources.[2] Clearly, the office will play an important role in facilitating responses to service demands within the state's energy-impacted communities because it has responsibility for determining not only which community will receive aid but also how much assistance each will receive. As presently organized, the program leaves local administrators and officials in a state of uncertainty as to whether they should prepare proposals and whether they will indeed receive funds for projects they propose. Also uncertain is the Office's budget, at least in the long-term.[3]

As well as affecting the governmental institutions and processes in the scenario area, energy development can be expected to affect the political activity and attitudes of the residents. Although practically no information exists concerning the effects on local government of population influxes associated specifically with energy development, conflicts between newcomers and area natives may produce noticeable effects on a community.

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[1] Rapp, Donald A. Western Boomtowns, Part I, Amended: A Comparative Analysis of State Actions, Special Report to the Governors. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976.

[2] North Dakota Century Code §§ 57-62-04 (Cumulative Supp. 1975).

[3] The Coal Development Impact Program is scheduled to last until June 30, 1977 unless renewed by the state legislature.

Energy development workers are a potential political force because their socioeconomic characteristics are generally associated with higher than average involvement in politics.[1] Also, they generally have urban viewpoints that conflict with the rural viewpoints of the local government personnel. (In this scenario area, as in most of the West, the present county governments are controlled by agricultural interests.) If long-time residents are willing to compromise with new interests (e.g., by channeling the increased revenues toward support of increased local services and amenities), then conflicts between the two groups may be minimized.

11.4.9 Summary of Social, Economic, and Political Impacts

Energy development in the Beulah area, especially strip mining and coal gasification, will cause population shifts over a three-county area focusing on Beulah and greater expansion in the Bismarck area. The greater population influxes will accompany facilities construction in 1985 and 1995-2000. An overall increase of 40,000 people in the area is expected by 2000, nearly 30,000 of which will probably live in the Bismarck-Mandan area. Temporary housing, particularly mobile homes, will have to provide shelter for construction boom periods. Mobile homes could become more permanent fixtures if the local homebuilding industry cannot provide the single-family and multi-family units that could be demanded by the year 2000.

School enrollment in Mercer County will be greatest in 1995 but will remain at least 50 percent above 1975 levels through the rest of the century. This indicates an average annual budget increase for schools in the county of about $2 million over current levels. New classroom needs will be small in comparison with other scenarios studies; the Bismarck-Mandan urban area will receive the greatest long-term impact, requiring 370 classrooms and $14 million in capital expenditures.

Agriculture's dominant position in the economy of the Beulah area will be replaced by coal-related sectors. New job opportunities will allow many local people and former North Dakotans to take energy development positions. As a result, median income in the area will rise about 50 percent over the 1975 level, although short-term peaks will occur during construction periods. In wholesale and retail services, Bismarck-Mandan will see increases in activity, while Beulah and Hazen may expand as local retail centers. Combined with increases in population, these economic changes may result in new political alignments and leadership.

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[1] For a discussion of the characteristics that are usually associated with a high level of involvement in political affairs, see Flanigan, William H. *Political Behavior of the American Electorate*, 2nd ed. Boston, Mass.: Allyn and Bacon, 1972.

Municipal services and related expenditures must increase substantially to provide the necessary services, which will be concentrated exclusively in the towns. Medical care is a particular problem area, especially since it is difficult to attract doctors to non-metropolitan locations. For example, the need for the doctors by 2000 in the Beulah area will be difficult to meet under current trends. Planning for and managing energy development-related impacts may require full-time professional personnel in local governments, rather than the current part-time nonprofessionals.

11.5 ECOLOGICAL IMPACTS

11.5.1 Introduction

The area evaluated in the Beulah scenario extends southward to the Heart River, eastward past the Missouri River, northward 10 miles beyond Lake Sakakawea (Garrison Reservoir), and westward to the Badlands of the Little Missouri. Most of the land is gently rolling prairie, crossed by a few streams. The climate is semiarid, with extreme annual variations in temperature. Climate (especially winter weather), topography, and soil types largely determine the nature of the native biota and its productivity. Agriculture has markedly altered the natural grassland ecosystem, reducing both the diversity and abundance of wildlife.

11.5.2 Existing Biological Conditions

Two major native biological communities are found in the area, each with characteristic animal and plant species indicated in Table 11-34. The more extensive is the mixed mid- and short-grass prairie that forms a nearly complete ground cover in upland areas.[1] More than half of this area is under cultivation, principally for wheat or forage crops, and the remainder is grazed. Antelope are important game species in the area. Black-footed ferrets are thought to be present but have not been confirmed. Both small birds and larger birds of prey are

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[1] Characteristic grassland herbs such as lupine, goldenrod species, and blazing-star, as well as silver sage, rabbitbrush, and other shrubs, lend diversity to the vegetation but do not contribute significantly to overall productivity or cover.

TABLE 11-34: SELECTED CHARACTERISTIC SPECIES OF MAJOR BIOLOGICAL COMMUNITIES

Community	Characteristic Plants	Characteristic Animals
Grassland-cropland mosaic	Needle-and-thread grass Western wheatgrass Blue grama Little bluestem Silver sage Blazing-star	Pronghorn antelope Jackrabbit species Ground squirrel species Badger Meadowlark Golden eagle Marsh hawk Short-horned lizard
Riparian Woodlands	Cottonwood Green ash American elm Burr oak Willow species Buffaloberry	Whitetail deer Porcupine Tree squirrel Skunk Mink Flycatchers Leopard frog Garter snake

numerous.[1] The peregrine falcon formerly bred on buttes and escarpments in the prairie habitat type but is now thought to be extinct as a breeding bird in North Dakota. Thousands of waterfowl nest and stop during migration on the many small lakes and marshes (an important duck production area).

The second major community is a variable woodland with its major development along the Missouri River Floodplain and tributaries.[1] The complex physical structure of these woodland areas, which provide a wide variety of nesting or denning sites and food sources, promotes a diversity of animal life, including a wide variety of birds.[2] Typical mammals of woodland habitats include porcupine, shrews, and whitefooted mice. Many predators and omnivores, including the red fox, mink, weasel, striped skunk, and raccoon, prefer the wooded floodplain or ravine habitats where there is both cover and a variety of prey. Game animals include wild turkey, cottontail rabbit, tree squirrels, and white-tailed deer, which also range into the praires adjacent to the major stream courses. To the west, along the course of the Little Missouri River, lies an area of eroded badland topography. Although beyond the immediate scenario area, these badlands may potentially have high recreational use.[3]

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[1] Bird faunas include a number of typical prairie species, including Western meadowlark, horned lark and lark bunting, golden eagle, Swainson's hawk, marsh hawk, red-tailed hawk, kestrel, merlin, prairie falcon, and burrowing owl. Upland game birds include sharptail grouse and Hungarian partridge. The ringnecked pheasant is particularly characteristic of agricultural areas.

Aquatic communities in the scenario area vary from small lakes in the glaciated prairie to the large impoundments on the Missouri River and its tributaries. Fisheries are principally of the warm-water type, except within and below reservoirs, where both warm-water and cold-water species occur. The Missouri River between Lakes Oahe and Sakakawea is considered to be one of the outstanding sport fisheries of the Great Plains.

The biota described above is subject to several man-made stresses which may intensify throughout the study period. Chief among these influences is the expansion of cultivated land since the early 1960's. Substantial reductions have occurred in the floodplain forest of the Missouri between Lake Sakakawea and Lake Oahe. Draining wetlands and eliminating fencerow vegetation has reduced cover for small animals and waterfowl. Agriculture also contributes sediment, pesticides, and nutrients from fertilizers, through runoff, and most impoundments in the western part of the state (except main stem reservoirs) are now heavily contaminated with nutrients (eutrophic).[1] Damming the Missouri River has reduced flooding and meandering. This change has apparently reduced productivity in the floodplain forest and promotes the replacement of successional cottonwood and willow stands by hardwoods.[2]

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[1] The bottomland forest consists of climax stands of green ash, American elm, box elder, and burr oak, with successional stands dominated by willow and cottonwood.

[2] Birds include large numbers of insect eaters such as the vireos, wrens, and flycatchers. The bald eagle once nested along the Missouri River, and an active nest was reported in 1975 for McLean County, within the study area, although it subsequently failed.

[3] Despite the harshness of the environment, wildlife is diverse within the badlands. Species for which these areas constitute especially high-quality habitat include mule deer, cottontail rabbit, and bighorn sheep (introduced in the 1950's and now present in huntable numbers). Many hawk and falcon species find good nesting habitat in the rugged terrain, as does the golden eagle. Prairie dog distribution follows the grassland portions of the badlands, and a black-footed ferret was sighted near Medora in 1973.

11.5.3 Major Factors Producing Impacts

In the first 5 years of the scenario, local ecological impacts will arise principally from the loss of biological communities from changed land-use, disturbance from construction of the power plant, and the influx of construction workers. In the second decade, however, the influence of substantial population increases will begin with two separate construction employment peaks occurring in 1987 and 1986. As discussed in Section 11.3, sewage discharges into Knife River and Spring Creek will probably follow the pattern of population growth to a degree. Population and construction activities will peak again between 1990 and 2000. Land withdrawal subject to reclamation during the study period is indicated in Table 11-34. During 1975-2000, additional land in the area will probably be put under cultivation.

TABLE 11-35: HABITAT LOSS: BEULAH SCENARIO
(acres)

Habitat	1975-1980	1980-1990	1990-2000	Post-2000[a]	Cumulative
Grassland/ Cropland	5,190	1,590	1,760	82,320	90,860
Valley Shrublands and Forests	160	100	30	2,080	2,370
Total	5,350	1,690	1,790	84,400	93,230

[a] Includes all mined lands for facilities constructed before 2000.

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[1] Henegar, D.L. "Fisheries Division, Western District and Statewide Research Report." North Dakota Outdoors, Vol. 38 (No. 7, 1976), pp. 18-20.

[2] Johnson, W.C., R.L. Burgess, and W.R. Keammerer. "Forest Overstory Vegetation and Environment on the Missouri River Floodplain in North Dakota." Ecological Monographs, Vol. 46 (Winter 1976), pp. 59-84.

11.5.4 Impacts

A. Impacts to 1980

The construction of the power plant and its associated water supply and transmission lines will remove a maximum of 5,190 acres of grassland/cropland habitat and 160 acres of woody vegetation (Table 11-35). The population of Mercer and Oliver Counties will grow about 35 percent, primarily in Beulah and the small towns nearby.

Based on present distributions of grazing and cropland, the 5,350 acres removed from agricultural production will consist of 1,750 acres now being grazed and 3,600 acres are now being cultivated. The land removed from grazing presently produces forage roughly equivalent to the amount consumed in a year by 50 cows with calves or 250 sheep.[1] By comparison, Mercer County had an inventory of 53,125 cattle and calves, and 2,192 sheep and lambs in 1974.[2]

The impact of lost cropland on yield will vary with weather conditions and with potential improvements in cultivation practices or plant varieties.[3] Using the current figure of 25 bushels per acre, the loss of 3,600 acres of cropland would reduce yield by a maximum of 90,000 bushels, assuming all cropland was in wheat. By contrast, 1,361,547 bushels of wheat were harvested in Mercer County in 1974.[4]

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[1] Grazing value of land is usually estimated in terms of acres per Animal Unit Month (AUM). An AUM is defined as the amount of forage required to support one cow with calf, or five sheep, for a month. AUM's relate only to production of forage used by sheep and cattle; differences in food habits make the unit inappropriate for wildlife. Assuming an average of 3 acres per AUM, the amount of potential forage production lost by 1980 is 580 AUM's.

[2] U.S., Department of Commerce, Bureau of the Census. *1974 Census of Agriculture; Preliminary Report, Mercer County, North Dakota*. Washington, D.C.: Government Printing Office, 1976.

[3] It has been suggested that North Dakota wheat yields could rise from 25 to 112 bushels per acre through such improvements. Stewart, Robert E., Jr., Alan Golbart, and Jerome Johnson, eds. *Conference on the Future of Agriculture in Southwestern North Dakota, Held at Dickenson State College, Dickenson, N.D., May 1973*. Little Missouri Grassland Study, Interim Report No. 3. Fargo, N.D.: Little Missouri Grassland Study, 1973.

[4] Bureau of Census. *1974 Census of Agriculture; Mercer County, North Dakota*.

The relatively small amount of habitat removed directly in this part of the scenario time frame is expected to have only locally adverse impacts on wildlife, mostly small species. A possible exception is the pronghorn antelope. Beulah lies in the center of an area of high-quality habitat, and the disturbance resulting from the construction of the power plant may cause some animals to avoid the area.

The presence of large construction forces has been correlated with increases in illegal big game hunting. However, in the Beulah area, almost all land is owned privately, and most landowners will probably post their lands as the first construction forces move into the area. While a certain amount of trespassing will probably occur, poaching is not expected to reduce the reproductive capacity of game populations. In this respect, the Beulah scenario differs from other scenarios where large amounts of unpatrolled public lands exist.

Construction populations will also increase the demand for legal hunting and fishing. While upland game (sharptail grouse, pheasant, Hungarian partridge, and cottontail) populations will probably be able to withstand this, increased use of the publicly owned game management areas may call for additional controls. The supply of deer, antelope, and turkey may not be sufficient to meet potential hunting demand.

Fisheries in the area are maintained by stocking, and the hatcheries presently supplying this area of North Dakota have slack capacity. Thus, existing fisheries are probably adequate to supply the increased demand of the 1975-1980 period.

If a reservoir of 11,000 acre-ft capacity is constructed on the Knife River to supply the Lurgi plant, the area's fishery potential will be changed. Situated upstream of the industrial sites, the reservoir would not be subject to siltation problems resulting from construction. The reservoir would trap sediment from the upper portion of the Knife River drainage which, in conjunction with controlled releases downstream, could help alleviate sedimentation problems in the lower Knife caused by either industry or agriculture. The lake itself would probably support a warm-water sport fishery. The river's present populations of sauger, walleye, pike, and channel cat would benefit from stabilization of downstream flows.

Population growth in the Beulah area may result in discharges of municipal sewage effluent, at least temporarily into the Knife River. Such discharges typically have large concentrations of dissolved oxygen. Depending on the quantities discharged and the base flow in the stream, these pollutants could cause serious problems for several miles downstream. Nuisance blooms of algae and lowered dissolved oxygen levels could result. If all of the towns affected by population booms were to discharge into the Knife or its tributary, Spring Creek, pollutants might have a localized impact on the Missouri River.

B. Impacts to 1990

Construction activities in the second scenario decade will bring the total acreage of grassland/cropland habitat lost to 7,040, along with 260 acres of shrublands or valley forests. Commencement of mining at the power plant and the first Lurgi plant will disturb additional amounts of grassland and cropland, depending on the rate of mining. Human population size will fluctuate markedly during this period, exhibiting two distinct peaks: one around 1981 and one around 1986. Also within this time frame, the urban area of Bismarck-Mandan will grow by roughly 25 percent.

The additional land removed from grazing and crop production during this decade, using the same assumptions in Section A above, would otherwise have produced the yearly forage requirements of roughly 16 cows with calves or 80 sheep, and an average yearly yield of 28,170 bushels of wheat, based on 1973 yield averages.

Habitat fragmentation due to urban and industrial growth around Beulah will probably begin by the end of the second scenario decade, affecting, for example, more than half of the high-quality antelope habitat around Beulah. The number of antelope using this area will decline, and the regional populations will reflect the loss of this key area. Deer using this same area will probably also show local declines because the Knife River Valley and Spring Creek are key habitats, providing food and protection from severe winter weather. The cyclical nature of unemployment could induce some workers to remain in the Beulah area between construction peaks, and ready access to deer populations, especially in winter, could make game poaching attractive. Antelope might also suffer, although their wide-ranging habits make access more difficult. If poaching becomes widespread, the number of deer and antelope that could safely be harvested by legitimate hunters would decrease.[1]

Demand for hunting and fishing will continue to increase over the 1980-1990 decade. Fishing pressure could exceed the capacity of existing hatcheries, but the two large reservoirs on the Missouri will probably continue to meet demands for fishing, especially if recent introductions of such open-water fish as coho, lake trout, and lake whitefish are successful. Upland gamebirds could become somewhat scarcer around Beulah and

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[1] Because illegal hunting takes pregnant females and nonbreeding young, it can reduce the number of breeding adults.

Bismarck-Mandan. Continued expansion of cropland and reduction of fencerow and roadside cover will also lower production of small game during the 1980-1990 time frame (particularly ring-necked pheasant, Hungarian partridge, and sharptail grouse). Demand for big game hunting will exceed supply by a growing margin.

Increased populations will also place greater demands on the more accessible outdoor recreational resources of the area. On or adjacent to the two mainstem Missouri reservoirs, most continuing human activity will be confined to specific public access areas, although displacement of game onto private land during hunting seasons is likely. Deterioration of plant communities due to recreational use is more likely to occur in the Little Missouri Badlands. Depending on the access and use restrictions placed on these lands by the Forest Service, there is a potential for serious erosion problems arising from vehicle use. Even with stringent regulations, a certain amount of illegal use of off-road vehicles is likely to occur due to the difficulty of enforcing regulations over such an extensive area. Presently, the Little Missouri channel is used in winter as a snowmobile course. Additional use, proportional to population increases, could place a potential stress on deer.[1]

Population peaks of the early and middle 1980's could result in temporary discharges of municipal sewage effluents into the Knife River and Spring Creek. Impacts of such discharge could be exacerbated in the 1980-1990 time frame if mine dewatering and runoff control results in lowered base flow in these two streams. The extent and seriousness of nutrient enrichment problems depends both on the amount and character of effluents discharged and on the base flows of affected streams.

C. Impacts to 2000

The last decade of the scenario includes the construction and operation of two mine-mouth Synthane plants, with a loss of 1,800 additional acres of grassland/cropland habitat and 40 acres of shrubland or woodland. Mining and reclamation will continue to alter acreage. Beulah and Hazen will be centers of the high construction population in 1995. The land removed from agricultural production in this decade would otherwise produce forage equivalent to the yearly requirements of roughly 16 cows with calves, or 80 sheep, and an average yearly yield of 32,970 bushels of wheat, based on 1973 yield averages.

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[1] A recently published study on white-tailed deer suggests that increased movement caused by harrassement could substantially increase energy metabolic expenditures. Moen, A.N. "Energy Conservation by White-Tailed Deer in the Winter." Ecology, Vol. 57 (Winter 1976), pp. 192-98.

Emissions of criteria air pollutants under most conditions will not result in ground-level concentrations likely to produce chronic damage to range or cropland vegetation. Sulfur dioxide concentrations similar to those causing chronic damage to wheat under experimental conditions may occur for brief periods. Therefore, sulfur dioxide emissions are not likely to significantly limit crop or forage yields. The addition of sulfur to mineral cycles as particulate fallout or rain washout might be beneficial in sulfur-deficient soils of the area.[1]

Trace elements, including mercury, fluorine, lead, arsenic, zinc, copper, and uranium, will be emitted chiefly from the power plants.[2] These elements will eventually enter the crop and grassland mineral cycles, but their pathways through the ecosystem are not well known. Therefore, the exact impact of their introduction cannot be predicted. Trace element buildup in both soils and vegetation has been recorded downwind of several power plants, but consequent toxic effects have not been documented.

D. Impacts After 2000

When all the scenario activities have been completed, a total of 82,320 acres of grassland/cropland and roughly 2,060 acres of tall shrubland will have been mined. The long-term ecological impact of mining will depend on the success of reclamation and the extent that mines are replaced by new croplands.

The climate of North Dakota is generally favorable for reclamation, and several land-use options are possible.[3] Restoration of mined areas for use as cropland is typically attractive because of its relatively low cost. It is also possible to restore these mined areas to a mixed-grass prairie, consisting

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[1] Painter, E.P. "Sulfur in Forages." North Dakota Agricultural Experiment Station Bimonthly Bulletin, Vol. 5 (No. 5, 1943), pp. 20-27.

[2] Some North and South Dakota lignites have locally high concentrations of uranium, in excess of 0.1 percent. Swanson, Vernon E., et al. Composition and Trace Element Content of Coal, Northern Great Plains Area, U.S. Department of the Interior Report 57-83. Washington, D.C.: Government Printing Office, 1974, p. 7.

[3] Sandoval, F.M., et al. "Lignite Mine Spoils in the Northern Great Plains: Characteristics and Potential for Reclamation," Paper presented before the Research and Applied Technology Symposium on Mined Land Reclamation. Pittsburg, Pa.: Bituminous Coal Research, Inc., 1973.

(at least in part) of native species, and suitable for grazing. Normal succession to a mature grassland in similar areas takes 15-20 years after disturbance.[1] Wildlife habitat values can be restored for many upland game species by the use of woody plantings for food and cover.[2]

The resemblance between reclaimed mined areas and early stages of grassland development may result in colonization by species which typically characterize early stages of grassland development, such as various ground squirrels, the western harvest mouse, and horned lark. In mature grasslands and successful reclaimed areas, antelope, sharptail grouse, jack-rabbits, and a variety of small birds (typified by the chestnut-collared longspur) are characteristically predominant. However, species adapted to croplands will differ little from those which may be expected to colonize newly reclaimed areas.

Certain overburden characteristics could potentially limit the success of reclamation, at least locally. High sodium levels occur in some of the strata overlying several existing mines in western North Dakota, and the problem appears to be widespread over the lignite fields of the Fort Union Formation.[3] Unless carefully buried, these layers could inhibit plant growth and prove highly susceptible to erosion. Further, even if buried, increased infiltration of water leaching through the unconsolidated spoil material could bring salts from these layers to the surface.

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[1] Aikman, J.M. "Secondary Plant Succession on Muscatine Island, Iowa." Ecology, Vol. 11 (July 1930), pp. 577-88. Tolstead, W.L. "Plant Communities and Secondary Succession in South-Central South Dakota." Ecology, Vol. 22 (July 1941), pp. 322-28.

[2] Early experience at the Knife River Coal Company's Beulah mine has shown that ungraded spoil piles, planted with a mixture of wildlife food plants, are abundant in upland species such as grouse, pheasant, and rabbits, which typically suffer heavy losses because of winter storms. Large numbers of white-tailed deer from the adjacent Knife River Valley also find shelter in the area. Legal provisions requiring that spoils be graded to resemble the original topography under these circumstances reduces potential value for wildlife.

[3] Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains. General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

The impact on agricultural production of facility siting by decade, and of progressive strip mining, is summarized in Table 11-36. Calculated losses due to mining assume that either grazing or cropland value will be fully restored in 5 years, but that mined lands would not be used for any agricultural purposes until then. This assumption is probably conservative. It was further assumed that each mine will be operated for 30 years, and that after the initial 5 years of operation, an amount of land equal to 17 percent of the total mine tract will be unreclaimed at any given time. As shown in the table, crop production could be strongly affected, although in practice not all of the acreage lost would be planted to wheat, which lowers the percentage loss as compared with 1974 harvest. Livestock production losses, however, would be insignificant.

11.5.5 Summary of Ecological Impacts

Table 11-37 summarizes the effects of the changes discussed above on the area's game species, rare or endangered species, and selected indicators of ecological change.

The major scenario influences on deer and antelope populations in the area are expected to be localized habitat fragmentation and, possibly, illegal harvest. This will probably be more important for area-wide antelope population because changes will occur to the less plentiful quality habitat.

Upland game is expected to begin a localized decline in the early 1980's. Wild turkey, with harvests carefully controlled by the state of North Dakota, will probably not show major declines attributable to the scenario. However, many species are likely to experience regionwide reductions in numbers as a result of clearing grasslands, wetlands, and river bottoms for agriculture.

Endangered species, including bald eagles and peregrine falcons that are occasionally seen in the area, may be adversely affected by the scenario. Both species are subject to illegal shooting. Bald eagles also tend to be sensitive to human disturbance within 1 or 2 miles of a nest; increased human population and activity along the Missouri would therefore reduce the likelihood of restoring a breeding population of eagles. The number of peregrines visiting the area is probably controlled by conditions in their breeding range; consequently, the potential impact of illegal shooting the Beulah area on the number of birds seen there from year to year is difficult to specify.

The black-footed ferret is known to be in the area from a recent sighting near Medora but has not been located in the Beulah vicinity. The major threat to this species, aside from

TABLE II-36: AGRICULTURAL PRODUCTION FOREGONE

Period	Cropland		Grazing Land		
	Acres Lost	Yield Foregone[a]	Acres Lost	Cows/Calves[b]	Sheep[b]
1975-1980	3,590	89,630	1,770	50	5
1980-1990	1,130	28,170	560	15	1
1990-2000	1,200	29,970	590	16	1
Post-2000[c]	8,880	222,105	4,780	130	7
Cumulative Total	14,800	369,870	7,700	211	14
Mercer-Oliver County Production 1974[d]		2,086,300		90,922	3,596
Cumulative Loss as % of County Production		18%		0.2%	0.4%

[a] Assuming all cropland is in wheat.

[b] Assuming 99 percent of all animal units are cattle, 1 percent sheep.

[c] Assuming that at equilibrium, 17 percent of all mined land is unreclaimed.

[d] Livestock inventory and wheat figures from U.S. Department of Commerce Census of Agriculture.

TABLE II-37: FORECAST FOR SELECTED SPECIES FOR THE BEULAH SCENARIO[a]

	[illegible]	[illegible]	[illegible]
Game Animals Antelope	Slight to moderate decline in density in Beulah area.	Moderate decline throughout Beulah area, possible reduction in huntable populations.	Marked decline throughout Beulah area, definite reduction in huntable populations.
White-tailed Deer	Little change or slight decline in density in Beulah area.	Slight decline in areawide populations, if illegal kills are high around Beulah. Possible slight decline in the Little Missouri Badlands if heavy recreational use.	Areawide numbers continued slightly below 1975 levels from habitat fragmentation, poaching, and recreational use in the Badlands. If mined lands reclaimed for wildlife, [illegible]
Sharptail Grouse, Hungarian Partridge, Pheasant	Little change.	Slight declines in density around Beulah.	Continued slight to moderate decline in areawide numbers unless mined lands are extensively reclaimed for wildlife values.
[illegible]	Little change.	Little change areawide. Local declines where strip mining eliminates habitat.	Little change areawide. Local declines from mining, most balanced by reclamation if adequate cover is provided.
Rare or Endangered Species: National Level Peregrine Falcon	Little change.	Possible loss of individuals due to illegal shooting.	Possible loss of individuals due to illegal shooting.
Black-footed Ferret	Little change, unless directly displaced by mining or facilities siting.	Little change, unless directly displaced by mining or facilities siting.	Little change, unless directly displaced by mining or facilities siting.
Bald Eagle	Little change.	Likelihood of reestablishing nesting pair along the Missouri River may be reduced.	Likelihood of reestablishing nesting pair along the Missouri River may be reduced.
Other Unusual Species [illegible]	Little change.	Possible loss of individuals through trapping and hunting for predators.	Possible loss of individuals through trapping and hunting for predators.

TABLE 11-37: (Continued)

	1980	1990	2000
Prairie Falcon, Ferruginous Hawk, Golden Eagle	Possible loss of breeding individuals due to illegal shooting.	Possible loss of breeding individuals due to illegal shooting.	Possible loss of breeding individuals due to illegal shooting.
Burrowing Owl	Possible localized losses due to habitat loss, probably not of a regional significance.	Possible localized losses due to habitat loss, probably not of a regional significance.	Possible localized losses due to habitat loss, probably not of a regional significance.
Mountain Plover	Little change.	Little change.	Little change.
Indicators of Ecological Change			
Mining and Reclamation			
Dickcissel, Chestnut-collared Longspur, Grasshopper Sparrow	Little change.	Local losses where strip mining eliminates habitat, continued low numbers on lands reclaimed for crop-land.	Continued local losses from mining. Return (in later stages of succession) to areas reclaimed to grazing land.
Horned Lark	Little change.	May become the dominant bird on reclaimed lands in early stages of succession, and lands reclaimed for crops.	Continued dominance on early succession reclamation land stages. Lowered dominance on late succession grasslands and areas reclaimed for wildlife.
Thirteen-lined Ground Squirrel	Little change.	If conditions favor burrowing may become abundant on reclaimed lands in early stages of succession.	Continued abundance on successional lands. Increasing as soil structure develops and improves conditions for burrowing.
Eutrophication			
Largemouth Bass	If dissolved oxygen concentrations fall below 4 milligrams per liter, bass will either avoid polluted water, or will be smaller in size.	If dissolved oxygen concentrations fall below 4 milligrams per liter, bass will either avoid polluted water, or will be smaller in size.	If dissolved oxygen concentrations fall below 4 milligrams per liter, bass will either avoid polluted water, or will be smaller in size.

aThis chart reflects the influence of the energy developments only. Continued expansion of cultivation under present U.S. Department of Agriculture policy will increase additional impacts.

direct destruction of habitat, would be through reduction of prairie dog numbers by varmint hunters.

The endangered Northern Kit (swift) Fox is susceptible to traps set for other species, and is mistaken for a young coyote by hunters. With increased numbers of people participating in these activities, this species could be reduced in numbers, or lost altogether.

Table 11-38 summarizes the major factors producing ecological impacts in the Beulah scenario area. These have been grouped into three classes, based on their geographic extent and the number of species they affect.

Sulfur dioxide pollution is given a Class C rating because its impact on vegetation, measured as productivity, will be at least an order of magnitude less than the effects of normal year-to-year variations in climatic factors and grazing pressure. The impact of land-use changes on agricultural production will likewise be small, usually less than .1 percent of county totals.

Most of the impacts of rising human populations fall into Class B, namely: illegal shooting, increased use of delicate badlands areas, and discharge of sewage treatment effluents into surface waters. Conversion of native rangeland to cropland as mining and reclamation proceed is also included. These impacts rate higher in severity because they can potentially alter the size of areawide populations of some animals or bring about shifts in community composition in habitats of restricted occurrence.

Class A impacts are considered to be the pivotal problems reponsible for the projected animal population impacts discussed above. In the Beulah scenario, habitat removal, fragmentation, and the incidental disturbances coincident with urban growth within an area of high-quality wildlife habitat. Most critically, these impacts are difficult to manage or reverse.

11.6 OVERALL SUMMARY OF IMPACTS

The intended energy benefit from the hypothetical developments in the Beulah area will be production and export of 3,000 megawatts-electric of electricity and 1 billion cubic feet per day of synthetic natural gas by the year 2000. Locally, the benefits include increases in retail trade, income to residents, state and local governments, and secondary economic development.

Social, economic, and political changes in the 3-county area will stem primarily from the overall 53-percent growth in population. The distribution of this growth will determine the severity of the impacts. The new jobs are expected to raise the median income in the area about 50 percent above the 1975 level,

TABLE 11-39: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

Impact Category	1975-1980	1980-1990	1990-2000
Class A	Direct removal and fragmentation of habitat. Zones of urban activity.	Direct removal and fragmentation of habitat. Zones of urban activity.	Direct removal and fragmentation of habitat. Zones of urban activity.
Class B	Illegal shooting. Discharge of municipal sewage effluents.	Illegal shooting. Discharge of municipal sewage effluents. Excessive recreational use of badlands. Conversion of native range to cropland via reclamation.	Illegal shooting. Excessive recreational use of badlands. Conversion of native range to cropland via reclamation.
Class C	Grazing, crop losses.	SO_2 emissions. Grazing, crop losses.	SO_2 emissions. Grazing, crop losses.
Enhancing Some Species	Reservoir on the Knife River.	Reservoir on the Knife River.	Reservoir on the Knife River.

The increased demand for housing will be largely met by mobile homes. Medical care and other professional services are expected to be seriously lacking throughout the three-county area. As a result of the development, agriculture's dominant position in the economy will be replaced by coal-related sectors. Exporting coal would significantly reduce both the adverse and beneficial effects of much of the population growth, as well as lower property tax benefits to local governments.

As presently configured, the planned facilities will have a minimal effect on the local air quality. The four gasification plants do not cause any North Dakota or federal ambient standards to be exceeded. However, although power plant emissions meet federal ambient standards, they exceed the North Dakota 1-hour sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) ambient standards. In addition, general urban development at Beulah will cause both the federal and state 3-hour hydrocarbons standards to be exceeded by 1985. Also, the plumes of the plants will be visible from many locations in the area, and the average long-range visibility will be reduced about 10 percent when all the facilities are operating and to a greater extent during periods of air stagnation.

The SO_2 emissions could be decreased through an improvement in scrubber efficiency, the pre-combustion washing of the coal, or through a reduction in plant operating capacity. Although scrubbers for NO_2 are still in the experimental stage, these emissions can be controlled, to a limited extent, by boiler firing modifications such as staged firing, low excess air, and reduction of plant capacity, or by exporting coal.

The water consumption attributed to the energy facilities and their associated development is not expected to significantly deplete groundwater or surface-water resources. Although there will be no intentional discharges of pollutants to groundwaters or surface waters, deterioration of local water quality may result from the failure of settling and holding ponds and the improper disposal of urban sanitary wastes. The integrity of the storage ponds may be breached via the leaching of chemicals through the pond liners or from the erosion of pond dikes; both possibilities will become more likely as the facilities age. Sewage disposal, although not presently a problem in the area, is expected to become serious as the urban growth out-paces the ability of municipalities to respond. This problem will be most evident during periods of peak growth which occur in the mid-1980's and mid-1990's.

Although surface waters are most abundant in this scenario, technological changes could further reduce depletions. The potential exists for using wet-dry cooling towers for the hypothetical conversion facilities in this scenario but at considerable expense. Local water quality could be mitigated through the installation of recyclable waste disposable systems or packaged systems for mobile home parks (which comprise a large portion of the new housing).

Ecological impacts in the scenario will stem largely from the population increases. Therefore, the area surrounding Beulah will probably be the most severely impacted. As a result of habitat fragmentation, the productivity of selected species will likely decrease. Poaching is also expected to be a serious problem unless positive steps are initiated in game protection and management. Other impacts of human activities will include simplification of ecosystem structure (with increases in relative abundance of fewer species) and loss of soil nutrients due to erosion.

Controls over human use of the area, such as permits for recreational use and zoning, would minimize attrition of habitat. Provisions for habitat control in the river valley, and habitat management programs on farmlands can also affect changes to vegetation and animal abundance.

CHAPTER 12

THE REGIONAL IMPACTS OF WESTERN ENERGY RESOURCE DEVELOPMENT

12.1 INTRODUCTION

This chapter reports the results of analysis of the regionwide impacts likely to occur when energy resources in the eight-state study area are developed. As Chapter 1 indicates, coal, oil shale, uranium, oil, gas, and geothermal resources are found within the eight-state area. Coal and oil shale are the most abundant and easily extractable; in fact, the region contains almost 40 percent of the nation's demonstrated coal reserves and 90 percent of the nation's identified oil shale resources. The region also contains 10 percent the nation's geothermal reserves, 90 percent of its uranium, 26 percent of its oil, and 8 percent of its natural gas reserves.

Although energy resources are scattered throughout the eight-state area, distribution patterns vary considerably among the resources. For example, coal is found in all eight states.[1] The largest concentrations are found in the Northern Great Plains. Large, high-grade oil shale deposits are concentrated in the Green River Formation in Colorado, Utah, and Wyoming. The largest deposits of uranium are found in New Mexico and Wyoming. Crude oil and natural gas reserves are also largest in New Mexico and Wyoming; however, both resources are also found in Colorado, Utah, and North and South Dakota. Geothermal resources have not been well identified but apparently occur in six of the eight states; the two exceptions are the Dakotas.[2]

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[1] See University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975.

[2] Data on all the resources are limited and often of questionable quality. Locating and defining resources have higher priorities now than before the 1973 energy crisis; however, data are still generally inadequate and will probably continue to be so for the near-term future.

Stanford Research Institute's (SRI) interfuel competition model was used to establish the three levels of energy resource development required in the eight states resulting from three projections of national energy demands between the present and 2000.[1] The SRI model was used because it is recent, readily available and well-documented, projects energy demand to the year 2000, analyzes multiple scenarios, and disaggregates geographically to the area of interest to this study. At the time a model was needed to establish levels of development for the eight western states, the SRI model was considered to be the best available. However, the overall national energy demands assumed are somewhat higher than are now being projected. At the time the SRI model was formulated, those demands were reasonable, but energy growth has fallen substantially since then and the projections now appear high. Some of the limitations of the SRI model include:

1. The contribution predicted from oil shale grows very rapidly in the 1990-2000 decade (from five to forty-two 100,000-barrels-per-day plants), although it now seems unlikely that development at that rate could be accomplished.

2. Western coal is assumed to be of one composition and heating value throughout the West. Actually, wide variations exist, such as between North Dakota lignite and Kaiparowits bituminous.

3. Only limited account is taken of the availability of equipment and personnel to accomplish the development indicated. As noted later in this chapter, both could tend to constrain developments to levels below those indicated.

4. Installation of flue gas desulfurization control equipment (stack gas scrubbers) is not considered on electrical power generating plants using western coal, and all coal was considered to be produced from surface mines.

5. Oil shale was considered to be produced solely from surface mines, and *in situ* oil shale retorting is not considered.

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[1] Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

These assumptions and omissions constrain the utility of the model; however, it does serve the primary purpose of this study, which is to determine the likely consequences if specified supply levels are drawn from the western U.S. During the remainder of the study, other models may be used to project future levels of development, or the SRI model may be modified.

The SRI model considers various combinations of energy resources that could supply energy demands at a particular location at a particular time. Estimates are made of the costs of delivered energy in a particular form from various sources, and an economic analysis is made to determine the quantity provided by each source of supply. For example, distillate fuel oil in Chicago could be supplied from: crude oil produced in Wyoming and piped to Chicago for refining; oil shale mined, retorted, and upgraded to synthetic crude oil in Colorado, then piped to Chicago for refining; or coal mined and converted to synthetic crude oil in Montana, then piped to Chicago for refining. Each of these "paths", as well as others, must be analysed as part of the entire U.S. energy system to determine the fraction of demand to be met by each resource at each location.

Three demand levels were assumed in the analysis of supply alternatives; these are SRI's Nominal, Low Demand, and Low Nuclear Availability cases. The Nominal case assumes a demand 30 percent of the way between the demands predicted by the Ford Foundation's Historical Growth and Technical Fix scenarios for the 1975-2000 period.[1] (The Historical Growth case examines the consequences of continuing an average growth rate in energy consumption of 3.5 percent per year. The Technical Fix case is an attempt to anticipate the results of a variety of voluntary and mandatory energy conservation measures.) The Nominal Demand case predicts an energy supply of 156.9 quads (Q) for the year 2000 and an end use demand of 79.98Q.[2]

The Low Demand case corresponds to the Ford Foundation's Technical Fix Scenario and results in an annual growth rate of approximately 2.1 percent. It predicts an energy supply of 129.5Q for the year 2000 with an end use demand of 67.97Q.

The Low Nuclear Availability case assumed nominal demand but constrained the analysis by assuming that no new nuclear power plants would be constructed and that existing nuclear plants would continue to operate until they wear out. This case was included because the Nominal case predicts that half of the electricity produced in 2000 will be nuclear (a prediction that now seems unlikely) and because if the development of nuclear power is constrained, coal production will be substantially increased. In effect, then, the Low Nuclear Availability case provides a high coal demand case to compare to the other two scenarios.

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[1] Ford Foundation, Energy Policy Project. *A Time to Choose: America's Energy Future*. Cambridge, Mass.: Ballinger, 1974.

[2] Cazalet, Edward, *et al*. *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976. Losses within the system account for the difference between the supply and end use demand numbers.

The projections for the three cases are given in Tables 12-1, 12-2, and 12-3. As used in the SRI model, the "Powder River Region" refers to the states of Montana, Wyoming, and North and South Dakota;[1] the "Rocky Mountain Region" includes New Mexico, Arizona, Utah, and Colorado. Allocations of national nuclear production were based on present production rates. The number of facilities required were calculated by assuming the typical facility sizes and capacity factors shown in Tables 12-1, 12-2, and 12-3 and determining how many standard-size facilities would be needed for the total production indicated.[2]

The geographical distribution of development was carried out on a regional basis by considering only two subregions, the Powder River Region and the Rocky Mountain area. Further disaggregation to states and counties within states was generally proportioned on the basis of where proven reserves are located. Some disaggregation was based on the location of announced energy facility development. This process was carried to the county level to support some of the subsequent analyses. However, depending on both the availability of land and support services and the legal structures involved, actual development may extend over an area that includes several counties.

In addition to regional impacts, this chapter reports the results of selected local, subregional, and national impact analyses. The local impacts considered are those common to all sites, for which existing data, the current state of knowledge, and/or analytical tool development are inadequate to support a site-specific analysis, or which are the aggregated local impacts of combinations of site-specific developments. Subregional impact analyses are limited to the major river basins in the eight-state area. The selected national impacts considered are limited to major economic and fiscal concerns, such as the availability of capital, materials, personnel, and equipment.

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[1] In the SRI model, the Powder River region includes the Powder River Basin and the Fort Union Basin. With several smaller geologic basins, this area may be considered equivalent to the Northern Great Plains Region.

[2] The disaggregations used here are based on the SRI model but were constructed by the Science and Public Policy Program-Radian research team.

TABLE 12-1: PROJECTION OF WESTERN ENERGY RESOURCE PRODUCTION
NOMINAL DEMAND CASE[a]

Energy Type	Total U.S. Production (Q)[b]					Fraction of U.S. Production from West (%)					Number of Facilities Required in Western Region[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Coal[d]															
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Unit Trains	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Slurry Pipeline	0	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gasification	0	0	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Liquefaction	0	0	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electrical Generation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oil Shale	0	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Uranium Fuel	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gas (Natural)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Domestic Crude Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountain						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Q = 10^{15} British thermal units. One Q = 170 million barrels of oil, [illegible] million tons of western coal, or 1 trillion cubic feet of natural gas.

[a] Based on Stanford Research Institute Nominal case and Ford Foundation data.

[b] [illegible]

[c] [illegible]

[d] Coal subcategories do not add to total because of other uses: for example, [illegible].

TABLE 12-2: PROJECTION OF WESTERN ENERGY RESOURCE PRODUCTION LOW DEMAND CASE[a]

Energy Type	Total U.S. Production (Q)[b]					Fraction of U.S. Production from West (%)					Number of Facilities Required in Western Region[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Coal[d]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Direct Use	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Unit Trains	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Slurry Pipeline	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gasification	0	0	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Liquefaction	0	0	0	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electrical Generation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oil Shale	0	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Uranium Fuel	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gas (Natural)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Domestic Crude Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[a] [illegible]

[b] [illegible]

[c] [illegible]

[d] [illegible]

TABLE 12-3: PROJECTION OF WESTERN ENERGY RESOURCE PRODUCTION LOW NUCLEAR AVAILABILITY CASE[a]

Energy Type	Total U.S. Production (Q)[b]					Fraction of U.S. Production from West (%)					Number of Facilities Required in Western Region[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Coal[d]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Direct Use	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
Unit Trains	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Slurry Pipelines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gasification	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Liquefaction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electrical Generation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oil Shale	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Uranium Fuel	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gas (Natural)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Domestic Crude Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Powder River						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rocky Mountains						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Q = 10^{15} British thermal units. One Q = [illegible] million barrels of oil, [illegible] million tons of western coal, or 1 trillion cubic feet of natural gas.

[a] [illegible]

[b] [illegible]

[c] [illegible]

[d] [illegible]

12.2 AIR IMPACTS

12.2.1 Introduction

This section estimates total particulate, sulfur dioxide (SO_2), nitrogen oxide (NO_x), and hydrocarbon (HC) emissions that could result from the three levels of development being analyzed between 1976 and 2000. Existing emission levels and air quality conditions in other areas of the country are included for comparison.

Based on the location of resources within the study area, the sub-areas for which emissions are projected are: Four Corners (San Juan County, New Mexico); Southern Utah (Kane and Garfield Counties, Utah); Rocky Mountains (Uintah County, Utah and Rio Blanco and Garfield Counties, Colorado); Powder River (Big Horn, and Rosebud Counties, Montana and Campbell, Johnson, and Sheridan Counties, Wyoming); and Western North Dakota (Billings, Bowman, Dunn, Hettinger, Slope, Stark, and Williams County, North Dakota).

12.2.2 Existing Conditions

A. Air Quality

Table 12-4 gives national ambient air quality standards for five criteria pollutants,[1] and average background levels for three of these pollutants. Based on the limited data available, ambient air quality in the eight-state study area appears good at present. Generally, ambient concentrations of particulates, SO_2, and nitrogen dioxide (NO_2) are much lower than national standards. However, because of the arid climate, short-term secondary standards for particulates are frequently violated by wind-blown dust.

Ambient concentration data for oxidants and HC are available only on an annual basis for the Rocky Mountain area of northwest Colorado; they range from 60-70 micrograms per cubic meter ($\mu g/m^3$) for ozone and about 130 $\mu g/m^3$ for HC.[2] Although ambient standards for these two pollutants are for short-term measurement periods (1-hour for oxidants and 3-hour for HC), annual concentrations are considered to be good estimates of short-term

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[1] Criteria pollutants are those for which ambient air quality standards are in force: particulates, sulfur dioxide, nitrogen dioxide, photochemical oxidants, hydrocarbons, and carbon monoxide.

[2] Although oxidants exist in many forms, measurements are specified only for ozone.

TABLE 12-4: REGIONAL AIR QUALITY AND NATIONAL STANDARDS[a]

(micrograms per cubic meter)

Pollutant	Background Level[b]	Ambient Standards	
		Primary	Secondary
Particulates			
Annual geometric mean	12-40	75	60
Maximum 24-hour[c]		260	150
SO_2			
Annual geometric mean	10-20	80	NA
Maximum 24-hour[c]		365	NA
Maximum 3-hour[c]		NA	1,300
NO_2			
Annual geometric mean	10	100	100
O_x			
Maximum 1-hour[c]		160	160
HC[d]			
Maximum 3-hour[c] (6-9 am)		160	160

HC = hydrocarbons
NA = not applicable
NO_2 = nitrogen dioxide
O_x = photochemical oxidants
SO_2 = sulfur dioxide

[a] 40 C.F.R. 50 (1976).

[b] These levels represent the range of measurements available across the eight-state study area. Although no short-term measurements are available for oxidants and HC, annual concentrations are considered good indicators of baseline concentrations. Annual averages are 60-70 micrograms per cubic meter ($\mu g/m^3$) for oxidants and 130 $\mu g/m^3$ for HC.

[c] Not to be exceeded more than once a year.

[d] The HC standard serves as a guideline for achieving oxidant standards.

concentrations in rural areas.[1] National standards for oxidants and HC concentrations are presently violated in many parts of the West.

B. Meteorology

Meteorological conditions, especially those governing the dispersion and long-range transport of pollutants, are important factors in any assessment of likely air quality impacts of resource development. Dispersion potential in the study area is generally best during spring and summer, and worst during winter, in part because afternoon mixing depths are highest during spring and summer and lowest during winter.[2] The southeastern part of the study area normally has the highest mixing depths while the northern part has the lowest. Wind speeds are highest in the eastern portions and lowest in the western.

Air stagnation can cause serious dispersion problems in the Upper Colorado River Basin during winter because large masses of dense, cold air may be trapped between the Rocky and Sierra Nevada Mountains. Sharp terrain differences west of the Rockies exacerbate this problem by trapping stagnant air in deep valleys. In contrast to the Upper Colorado, the Upper Missouri River Basin has much less air stagnation because of higher winds and less rugged terrain.

Long-range transport of sulfates and fine particulates can create pollution problems considerable distances from energy facilities. Current knowledge of air parcel trajectories suggests that, during summer, the air mass trajectories which both precede and follow fronts may carry parcels containing pollutants from development areas to the Denver area.[3] However, during this movement, most pollutants may be dispersed or filtered from the parcels. Air parcels following fronts may carry air from the Powder River Basin to the Denver area; those that precede fronts may carry air to Denver from the Four Corners area.

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[1] Annual averages would not be good estimates of short-term concentrations in areas affected by man-made sources such as automobiles, energy facilities, etc.

[2] Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[3] Denver and Salt Lake are currently the most seriously polluted areas of the eight-state study area. We have no indication of air parcels from energy development being carried to the Salt Lake area.

12.2.3 Impacts

A. Introduction

Emissions from the energy facilities deployed in our scenarios will depend on the technology and the composition of the coal used at each facility. Table 12-5 gives projected emissions levels for each technology, given the coal compositions assumed for each area. This information shows that power plants are expected to emit the most particulates, SO_2, and NO_x and that Synthoil liquefaction and TOSCO II (the Oil Shale Corporation) oil shale retorting are expected to emit the most HC. Generally, Synthane gasification would emit the fewest total pollutants, except for NO_x in which case the TOSCO II retorting process will have the smallest total emissions.

The increase in emissions of each pollutant as a result of population growth attributable to energy resource development is equal to the estimated population growth times an urban emission rate. Population growth estimates are reported in Section 12.5. As indicated in the Introduction to Part II, each urban emission rate represents the average of the emission rates for several cities in the region. The largest urban emission rates would be for HC and NO_x (93 and 76 tons per year (tpy) per 1,000 population, respectively); the smallest would be for SO_2 and particulates (10 and 19 tpy per 1,000 population, respectively).

B. Impacts in Regional Sub-areas

1. Emissions

Emissions in 1975 for each of the five sub-areas and the Low Nuclear Demand case for the year 2000 are shown in Table 12-6.[1] Emissions for these two cases represent the baseline and maximum emissions expected for each sub-area.

Mathematical models that relate regional emissions to ambient air concentrations are currently in an embryonic state. Available models require in-depth analyses of the region's meteorology and climatology, which were beyond the scope of the first phase of this study. Thus, the analysis of regional air quality impacts was limited to the use of indices and estimates of expected changes in emissions over 1975 levels.

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[1] See the description of the Stanford Research Institute's Low Nuclear Demand, Low Demand, and Nominal cases in the Introduction to this chapter.

TABLE 12-5: EMISSIONS FROM ENERGY FACILITIES
(thousands of tons per year)

Facility	State	Particulates	SO_2	NO_x	HC
3,000-MWe power plant 70% load factor	New Mexico	9.3	30	59	1.7
	Utah	6.3	13	46	1.3
	Colorado	3.4	16	44	1.2
	Montana	8.6	43	58	1.4
	Wyoming	3.7	26	49	1.7
	North Dakota	9.3	43	65	2
250-MMscfd Lurgi gasification plant, 90% load factor	New Mexico	1.7	19	11	.39
	Montana	1.8	2.7	9.5	.35
	Wyoming	1.8	1.8	9.6	.34
	North Dakota	2	2.7	9.7	.35
24-MMscfd Synthane gasification plant, 90% load factor	New Mexico	.84	.91	6.1	.56
	Montana	.87	1.9	5	.25
	Wyoming	.84	.97	3.9	.62
	North Dakota	2.7	3.8	8.6	.39
100,000-bbl/day Synthoil liquefaction plant, 90% load factor	New Mexico	3	4.7	23	6.9
	Montana	1.3	3.8	19	5.5
	Wyoming	1.3	3.8	13	5.5
	North Dakota	1.3	3.8	19	5.5
100,000-bbl/day TOSCO II oil shale retort, 90% load factor	Utah	1	12	4.5	5.6
	Colorado	1	12	4.5	5.6

bbl/day = barrels per day
HC = hydrocarbons
MMscfd = million standard cubic feet per day

MWe = megawatts-electric
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

TABLE 12-6: SUB-AREA EMISSIONS, 1975 and 2000
(thousands of tons per year)

Pollutant	Resource Sub-Area	Emissions	
		1975	Low Nuclear Demand Scenario, 2000
Particulates	Four Corners	24	56
	Southern Utah	.5	26
	Rocky Mountains	3.5	57
	Powder River	9.9	160
	Western North Dakota	29	210
SO_2	Four Corners	.2	130
	Southern Utah	.2	54
	Rocky Mountains	.5	540
	Powder River	2.3	600
	Western North Dakota	54	710
NO_x	Four Corners	110	300
	Southern Utah	.9	190
	Rocky Mountains	3	290
	Powder River	11	1,100
	Western North Dakota	43	1,100
HC	Four Corners	14	33
	Southern Utah	1.5	21
	Rocky Mountains	4.1	260
	Powder River	15	150
	Western North Dakota	11	130

HC = hydrocarbons NO_x = nitrogen oxides SO_2 = sulfur dioxide

Table 12-7 presents "factor increases", or the ratio of predicted emissions in 2000 to 1975 emissions for each sub-area. These data are shown for each of the three levels of energy resource development.[1] This information shows that the Rocky Mountain sub-area is expected to have the highest emission increases among the five sub-areas; emissions would increase as much as 1,080 times for SO_2, 97 times for NO_x, and 63 times for

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[1] Note that these emission factors are based on assumptions made about national energy demands which now appear to have overestimated domestic resource development. A sensitivity analysis of these assumptions will be undertaken during the remainder of the project. Refer to the Introduction to Part II for an explanation of these predictions.

TABLE 12-7: EMISSION INCREASES, 1975-2000

Pollutant	Resource Subarea	Factor Increase in Emissions[a]		
		Energy Demand Scenario		
		Nominal	Low	Low Nuclear
Particulates	Four Corners	1.5	1.5	2.3
	Southern Utah	30	16	59
	Rocky Mountains	16	12	16
	Powder River	12	9.3	16
	Western North Dakota	5.6	4	7
SO_2	Four Corners	1.2	1.2	1.7
	Southern Utah	120	61	240
	Rocky Mountains	1,200	930	1,200
	Powder River	160	135	260
	Western North Dakota	9.3	6.5	13
NO_x	Four Corners	1.2	1.2	2
	Southern Utah	53	52	550
	Rocky Mountains	84	58	97
	Powder River	68	57	104
	Western North Dakota	20	13	27
HC	Four Corners	2.2	1.8	3.5
	Southern Utah	7.4	4	14
	Rocky Mountains	65	54	64
	Powder River	6.9	6.3	10
	Western North Dakota	9.4	6.4	12

HC = hydrocarbons NO_x = nitrogen oxides SO_2 = sulfur dioxide

[a] "Factor increases" are the predicted change in total emissions by the year 2000 compared to 1975 emissions.

HC over this time period depending on the energy demand scenario. These increases can be largely attributed to expected levels of coal development.[1]

Southern Utah is similar to the Rocky Mountain sub-area in baseline emissions and growth in resource development. Emissions in the Southern Utah sub-area may increase 550 times for NO$_x$ and 240 times for SO$_2$ in the Low Nuclear Demand scenario. The lowest emission increases would occur in the Four Corners sub-area, which had a large amount of development in 1975 (2,500 megawatts of electric power generation) and which, in our scenarios, would experience a small increase in new power facilities through the year 2000. Based on these assumptions, this sub-area would have the smallest emission increases for all pollutants at each level of resource development.

2. Emission Densities

Emission density, the total emissions in an area divided by the square miles of that area, is a second indicator of air quality in a sub-area or state. Table 12-8 projects 1975-2000 emission densities in each resource sub-area for Stanford Research Institute's (SRI) Low Demand, Nominal, and Low Nuclear cases.

In the Low Demand case, emission densities of particulates, SO$_2$, NO$_x$, and HC would increase between 1975 and 2000 in each sub-area.[2] By 2000, the highest emission densities are projected for SO$_2$ (as high as 40 tpy per square mile in the Rocky Mountain sub-area) and NO$_x$ (as high as 34 tpy per square mile in western North Dakota). SO$_2$ emission densities would also be high (30 tpy per square mile) in the Four Corners area by 2000 (this area had by far the largest 1975 emission density). The largest change would occur in the Rocky Mountain sub-area, where SO$_2$ density could increase by approximately 1,000 times by the year 2000.

With the exception of Southern Utah, all sub-areas are expected to have relatively high densities of NO$_x$ by 2000, ranging from 16 tpy per square mile (Rocky Mountains) to 34 tpy

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[1] Although this area is primarily known for its oil shale resources, it is also rich in coal deposits. Refer to the Introduction to this chapter for projections of energy resource production throughout the eight-state area.

[2] Because Stanford Research Institute's demand projections now appear to overestimate levels of western energy resource development, we emphasize the Low Demand case as the most realistic of the three projections. For an explanation of future modifications of these projections, see White, Irvin L., et al. Work Plan for Completing a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 12-8: EMISSION FROM ENERGY FACILITIES
(tons per year per square mile)

Resource Region	1975	1985			1990			2000		
		Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear
Particulates										
Four Corners	4.3	6	4.3	6	6	6	7.7	8.8	9.6	9.9
Southern Utah	.05	.77	.77	.77	1.5	.77	2.2	1.9	.77	2.9
Rocky Mountains	.33	.33	.33	.33	2.2	.88	1.1	5.1	6.1	5.6
Powder River	.40	.93	.88	1.6	2.6	2	3.1	4.7	2.7	6.5
Western North Dakota	1.8	2.9	2.6	2.9	5.5	4.3	6.5	10	7.1	10
SO_2										
Four Corners	26	29	26	30	40	30	55	33	33	61
Southern Utah	.02	1.5	1.5	1.5	3	1.5	4.5	3	1.9	5.9
Rocky Mountains	.06	.06	.06	.06	7.6	5.7	6.3	40	40	58
Powder River	.39	2.6	2.6	5.2	21	7.7	23	15	11	20
Western North Dakota	3.7	8.4	8.4	8.6	29	26	26	31	22	40
NO_x										
Four Corners	30	31	30	31	31	31	41	30	33	50
Southern Utah	.33	5.2	5.2	5.2	10	5.2	25	30	5.3	31
Rocky Mountains	.29	.29	.29	.29	6.7	2.8	6.3	28	16	27
Powder River	.40	4.8	4.8	9.2	27	26	31	35	23	46
Western North Dakota	3.6	20	20	22	30	20	35	51	36	60
HC										
Four Corners	2.5	3.6	2.6	3.6	3.7	3.6	4.6	4.2	3.9	4.1
Southern Utah	.27	.71	.46	.71	1.2	.71	1.7	2.2	.71	2.3
Rocky Mountains	.18	.30	.30	.30	2.4	1.3	2.9	25	21	30
Powder River	.41	1.1	1.1	1.6	2.5	2.1	3.1	6.3	3.9	6.2
Western North Dakota	.45	2.5	2.5	2.5	2.5	2.6	4.3	6.2	4.1	7.9

HC = hydrocarbons
NO_x = nitrogen oxides
SO_2 = sulfur dioxide

per square mile in Western North Dakota. As is true for SO_2, Four Corners is the only sub-area with relatively high densities of NO_x in 1975 (20 tpy per square mile). Hence, each of the other sub-areas can be expected to experience a large increase in NO_x density by the year 2000, ranging from a 12-fold increase in Western North Dakota to a 64-fold increase in the Powder River sub-area.

Neither HC nor particulates are expected to increase as rapidly as the other pollutants or have such high total density levels by the year 2000. The exception would be the HC density in the Rocky Mountain sub-area, which could reach 20 tpy per square mile by 2000. In each of the other sub-areas, HC levels were predicted to be relatively low in 1975 (0.17-2.5 tpy per square mile) and are expected to remain relatively low through the year 2000 (0.7-4.1 tpy per square mile). Similarly, particulate densities were relatively low in each sub-area in 1975 (0.77-7.1 tpy per square mile) and are expected to remain relatively low by the year 2000 (0.72-5.3 tpy per square mile).

In summary, Four Corners had the highest 1975 emissions density for all pollutants for all sub-areas. Projections based on SRI's Low Demand case suggest that Southern Utah will have the lowest densities of all pollutants by the year 2000. The Rocky Mountain (for SO_2 and HC) and Western North Dakota sub-areas (for NO_x and particulates) are expected to have the highest emission densities by the year 2000.

In the other two SRI cases, the five sub-areas generally have the same relative ranking for each pollutant as described for the Low Demand case. In each time period, regional emission densities generally would be higher for the Nominal than the Low Demand case and highest for the Low Nuclear case. The Western North Dakota and Southern Utah sub-areas would have substantially higher emission densities in the year 2000 for the Low Nuclear case than they do for the other two cases. This difference results from the large growth in electrical generation facilities for these two sub-areas for the Low Nuclear case in the year 2000 as compared to the other two cases.

C. Impacts in States

1. Emissions

Table 12-9 lists 1975 emissions levels and projected emissions in 1980, 1990, and 2000 for each SRI demand case in New Mexico, Colorado, Utah, Montana, Wyoming, and North Dakota. This information shows that, in 1975, Wyoming had the lowest total emissions of NO_x and HC, Colorado had the lowest SO2, and Utah had the lowest particulate emissions. Conversely, Montana exhibited the highest levels of particulates, SO_2, and HC, while New Mexico had the highest NO_x emissions. In comparison with

TABLE 12-9: PROJECTED EMISSIONS IN SIX WESTERN STATES[a]

(thousands of tons per year)

State	1975	1980			1990			2000		
		Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear
New Mexico										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Colorado										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Utah										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Montana										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wyoming										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Dakota										
Particulates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulfur Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrogen Oxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hydrocarbons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] [illegible]

TABLE 12-10: EMISSIONS IN SELECTED STATES IN 1972[a]
(thousands of tons per year)

State	Particulates	SO_2	NO_x	HC
Ohio	1,947	3,290	1,210	1,272
California	1,110	434	1,830	2,380
Georgia	446	521	408	505
Washington	179	301	207	380
Texas	606	830	1,440	2,450
Iowa	239	312	267	349

HC = hydrocarbons
NO_x = nitrogen oxide
SO_2 = sulfur dioxide

[a] U.S., Environmental Protection Agency. National Emissions Report, EN-226. Research Triangle Park, N.C.: National Environmental Research Center, 1974.

total emissions in selected states outside the region, these levels are relatively low (Table 12-10). For example, 1975 particulate levels in the six states listed in Table 12-9 ranged from 79,000 to 301,000 tons, which can be compared with 1972 levels measured in Iowa (239,000 tons), California (1,100,000 tons), and Ohio (1,947,000 tons). Similarly, 1975 emissions of SO_2, NO_x, and HC in most of the six western states were generally lower than 1972 emissions found in low or moderately industrialized states, such as Iowa or Georgia, and much lower than those found in highly industrialized states such as Ohio or California.[1]

On a state-by-state basis, the increases in emissions for the study area states listed in Table 12-9 follow the same general trends found in the resource sub-areas. In the Low Demand case, Montana is projected to have the highest emissions of particulates and SO_2 by the year 2000, while North Dakota and Colorado are projected to have the highest NO_x and HC emissions, respectively. In the six states listed, NO_x emissions generally would increase the most, ranging from 151,000 to 616,000 tons in 2000 as compared with 80,000 to 270,000 tons in 1975. SO_2 emissions are also expected to show large increases by 2000, while particulate emissions are expected to be only slightly higher than 1975 levels.

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[1] This finding is stated for purposes of comparison only. We do not intend to imply that the degradation that would be experienced would be either acceptable or unacceptable.

Table 12-11 shows projected SO_2 emissions for these same six states under the assumption that no scrubbers would be used on western power plants.[1] For the Low Demand case, total SO_2 emissions by 2000 (294,000-2,060,000 tons) are expected to be well below 1972 SO_2 emissions in Ohio (3,290,000 tons). However, Ohio SO_2 emissions were by far the highest for the states listed in Table 12-10. Only in the Low Nuclear case do projected SO_2 emissions in 2000 for two states, Montana and North Dakota, approach 1972 levels in Ohio.

2. Emission Densities

Table 12-12 shows 1975 projected emission densities in six western states for SRI's three demand cases. In general, increases in emissions densities from 1975 to 2000 can be expected to follow the same trends as found in the resource sub-areas, although densities would be much lower because of the larger area being considered. In the Low Demand case, the highest densities by the year 2000 generally would be SO_2, which would range from 1.5 tpy per square mile in Wyoming to 8.2 tpy per square mile in Montana. An exception to this would be the NO_x density in North Dakota in 2000 (8.7 tpy per square mile). For every state except Colorado, particulate and HC densities by 2000 are expected to be lower than SO_2 and NO_x densities. The lowest emissions densities in 2000 are expected to occur in New Mexico (particulates and NO_2) and Wyoming (SO_x and HC).

Increases in emission densities from 1975 levels are not expected to be large, compared to those found for the resource sub-areas. For example, SO_2 densities would increase 8-92 percent in New Mexico, Utah, Wyoming, and Montana. Larger increases would occur in North Dakota (225 percent) and Colorado (over 700 percent). These increases can be compared to SO_2 density increases of 1,000 times in the Rocky Mountain sub-area (a 100,000-percent increase).

Table 12-13 shows projected SO_2 increases in emission densities in these same six states if scrubbers are not used on power plants. For the Low Demand case, not using scrubbers would have only a slight effect on SO_2 densities in New Mexico, Colorado, and Utah in 2000. (In Colorado these densities would be the same as those projected for 2000 if scrubbers are used.) In New Mexico and Utah, the densities are expected to increase by 23 percent and 35 percent, respectively. Not using scrubbers would have a greater impact in Montana, Wyoming, and North Dakota; SO_2 densities would increase to 14 tpy per square mile in Montana and to 20 tpy per square mile in North Dakota. Compared

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[1] Power plants in New Mexico, Montana, and North Dakota will exceed Federal New Source Performance Standards for SO_2 emissions under this assumption. See Chapters 7, 10, and 11 of this report.

TABLE 12-11: PROJECTED SULFUR DIOXIDE EMISSIONS WITHOUT SCRUBBERS
(thousands of tons per year)

Scenario	1975	[illegible]			[illegible]			[illegible]		
		Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear
State New Mexico [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 12-12: PROJECTED EMISSIONS DENSITIES IN SIX WESTERN STATES
(tons per year per square mile)

State	1975	[illegible]			[illegible]			[illegible]		
		Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear
New Mexico [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Utah [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wyoming [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 12-13: PROJECTED SULFUR DIOXIDE EMISSION DENSITIES WITHOUT SCRUBBERS
(tons per year per square mile)

Year Scenario	1975	[illegible]			[illegible]			[illegible]		
		Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear	Nominal	Low	Low Nuclear
State New Mexico [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

to SO_2 densities in 2000 if scrubbers are used, the largest percentage increases would occur in Wyoming (167 percent) and North Dakota (400 percent).

12.2.4 Inadvertent Weather Modification

Very little data exist on the effects of energy developments on local or regional weather patterns. In areas where information is available, little agreement exists about the extent of potential problems. However, several categories of potential impacts have been identified: increased precipitation and cloud growth, fogging and icing, reduced visibility, turbidity, salt deposition, and acid rainfall. Occurrence of these phenomena throughout the eight-state study area will depend on the meteorology and climatology of the region, the size of energy facilities, the spacing and height of effluent stacks, and methods of heat dissipation.

A. Fogging and Icing

Properly designed and maintained cooling towers are expected to have negligible effects on[1] local fogging and icing conditions. However, others claim that both cooling towers and ponds contribute to local climate. These impacts appear most likely to occur during high relative humidities during winter.

Cooling ponds have been found to produce frequent fogging conditions, which are normally restricted to an area relatively close to the pond.[2] Cooling towers produce less frequent fogs, but when they do, they usually affect a much larger area.

Cooling towers and ponds can also contribute to icing, normally between late November and early April in most of the areas where energy resource development will take place. Icing build-up rates in the Four Corners area range from 0.2 to 13 millimeters per hour, averaging 1.54 millimeters per hour.[3] Icing build-up generally does not occur when the temperature is above 24°F.[4] Plumes can also contribute to road icing.

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[1] Spurr, G. "Meteorology and Cooling Tower Operation." *Atmospheric Environment*, Vol. 8 (April 1974), pp. 321-24.

[2] Currier, Edwin L., Joseph B. Knox, and Todd V. Crawford. "Cooling Pond Steam Fog." *Journal of the Air Pollution Control Association*, Vol. 24 (September 1974), pp. 860-64.

[3] *Ibid*.

[4] Martin, A., and F.R. Barber. "Measurements of Precipitation Downwind of Cooling Towers." *Atmospheric Environment*, Vol 8 (April 1974), pp. 373-81.

B. Precipitation

Energy development may also change precipitation patterns downwind of large facilities. However, considerable uncertainty exists about what changes will occur. Some information suggests that power plant emissions do not affect total rainfall levels[1] and that development of "heat islands" around developments cause overseeding of clouds which leads to decreased total precipitation.[2] However, other information suggests that large power parks can form cumulus clouds to heights over 5 miles, which could be accompanied by an inflow of local surface air, thunderstorms, and small tornadoes.[3]

In general, three characteristics of energy facilities have been related to weather modification:

1. Particulate loading, from either stack effluents or wind erosion from strip mines, may either increase or decrease precipitation depending on the size, distribution, and concentration of the particles. Particulate loading may also increase atmospheric turbidity, leading to decreased visibility and decreased sunlight intensity, which may in turn decrease afternoon showers.[4]

2. Heat islands from plants generally increase cloud growth, depending on the size of the plant and how high the plumes rise from the stacks. Cloud growth may increase precipitation unless overseeding occurs.

3. Moisture from cooling towers and ponds is likely to increase precipitation downwind of power plants.

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[1] Martin, A., and F.R. Barber. "Measurements of Precipitation Downwind of Cooling Towers." Atmospheric Environment, Vol 8 (April 1974), pp. 373-81.

[2] Bryson, Reid A. Climatic Modification by Air Pollution, Report #1. Madison, Wis.: University of Wisconsin, Institute of Environmental Studies, 1972.

[3] Hanna, Steven R., and Franklin A. Gifford. "Meteorological Effects of Energy Dissipation at Large Power Parks." Bulletin of the American Meteorological Society, Vol. 56 (October 1975), 1069-75.

[4] The relationship between turbidity and solar radiation intensity has been disputed. See Pueschel, Rudolf F., Charles J. Garcia, and Richard T. Hansen. "Solar Radiation: Effects of Atmospheric Water Vapor and Volcanic Aerosols." Journal of Applied Meteorology, Vol. 13 (April 1974), pp. 397-401.

12.2.5 Summary

Emissions and emission density levels have been calculated for resource sub-areas and for six of the eight states in the study area. Calculations have been made from the present to the year 2000 for SRI's Low Demand, Nominal, and Low Nuclear cases. Estimates fo air impacts in this section emphasize the Low Demand case because it appears to be a more realistic estimate of future energy development levels.

The Rocky Mountain sub-area is expected to experience the highest emission increases among the five sub-areas examined. Emissions in this area are projected to increase as much as 1,200 times for SO_2, 97 times for NO_x, and 65 times for HC by the year 2000. The density of SO_2 emissions are also expected to be highest in the Rocky Mountain sub-area, reaching 40 tpy per square mile by 2000. The Southern Utah sub-area should have the lowest densities of all pollutants by the year 2000.

On a state-by-state basis, both SO_2 and NO_x will have large emission increases by 2000. The largest SO_2 emissions are projected for Montana and the largest NO_x emissions for North Dakota. Particulates are expected to increase only slightly over 1975 levels.

Air impacts will be more serious if scrubbers are not used on western power plants. The most affected state would be Montana, where over 2 million tpy of SO_2 would be generated by 2000. Utah would have the lowest total emissions (294,000 tons) of the six states by the year 2000. Emissions of SO_2 would also increase substantially in North Dakota. Although total emissions (1.4 million tons) would be less than for Montana, North Dakota's rate of increase would be much faster (about a 16-fold increase compared to Montana's two-fold increase). Utah would have the lowest total emissions (294,000 tons) of the six states by the year 2000.

Urban pollution in Denver may increase as a result of the long-range transport of pollutants from the Powder River and Four Corners areas. Assessing the likelihood of this impact is difficult due to potential cleansing of air over long distances and the affects of the mountainous terrain.

Changes in precipitation due to weather modification caused by energy facilities may occur, particularly if several facilities are sited close together. However, more research is needed to reach reliable conclusions about this impact.

12.3 WATER IMPACTS

Water impacts have been evaluated for the Upper Colorado and Upper Missouri River Basins. Impacts in these basins are estimated for the three levels of development and time frames described in the Introduction to Part II and in Section 12.1.

12.3.1 Upper Colorado River Basin

The Upper Colorado River Basin (UCRB) includes parts of Wyoming, Utah, Colorado, Arizona, and New Mexico. It can be divided into three subregions associated with the Green River, the Upper Main Stem of the Colorado River, and the San Juan River as shown in Figure 12-1.

A. Existing Conditions

1. Surface Water

The impacts resulting from the consumption of the water required for energy development in the UCRB are largely determined by the quantity of surface water available in the basin. Estimates of the magnitude of this supply depend on interpretations of the Colorado River Compact[1] and the methods estimators used. The three most commonly cited estimates are:

1. The Department of the Interior's Water for Energy Management Team[2] estimates that at least 5.8 million acre-feet per year (acre-ft/yr) are available for consumptive use in the UCRB. Their estimate is based on releasing 8.25 million acre-ft/yr to the Lower Basin and allowing for shortages to irrigation users during subnormal years.

2. *Water Supplies of the Colorado River*, 1965[3] was a consultants study for the Upper Colorado River Commission which determined that 6.3 million

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[1] Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[2] U.S., Department of the Interior, Water for Energy Management Team. *Report on Water for Energy in the Upper Colorado River Basin*. Denver, Colo.: Department of the Interior, 1974.

[3] Tipton and Kalmbach, Inc. *Water Supplies of the Colorado River*, in U.S., Congress, House of Representatives, Committee on Interior and Insular Affairs. *Lower Colorado River Basin Project. Hearings* before the Subcommittee on Irrigation and Reclamation, 89th Cong., 1st sess., 1965, p. 467.

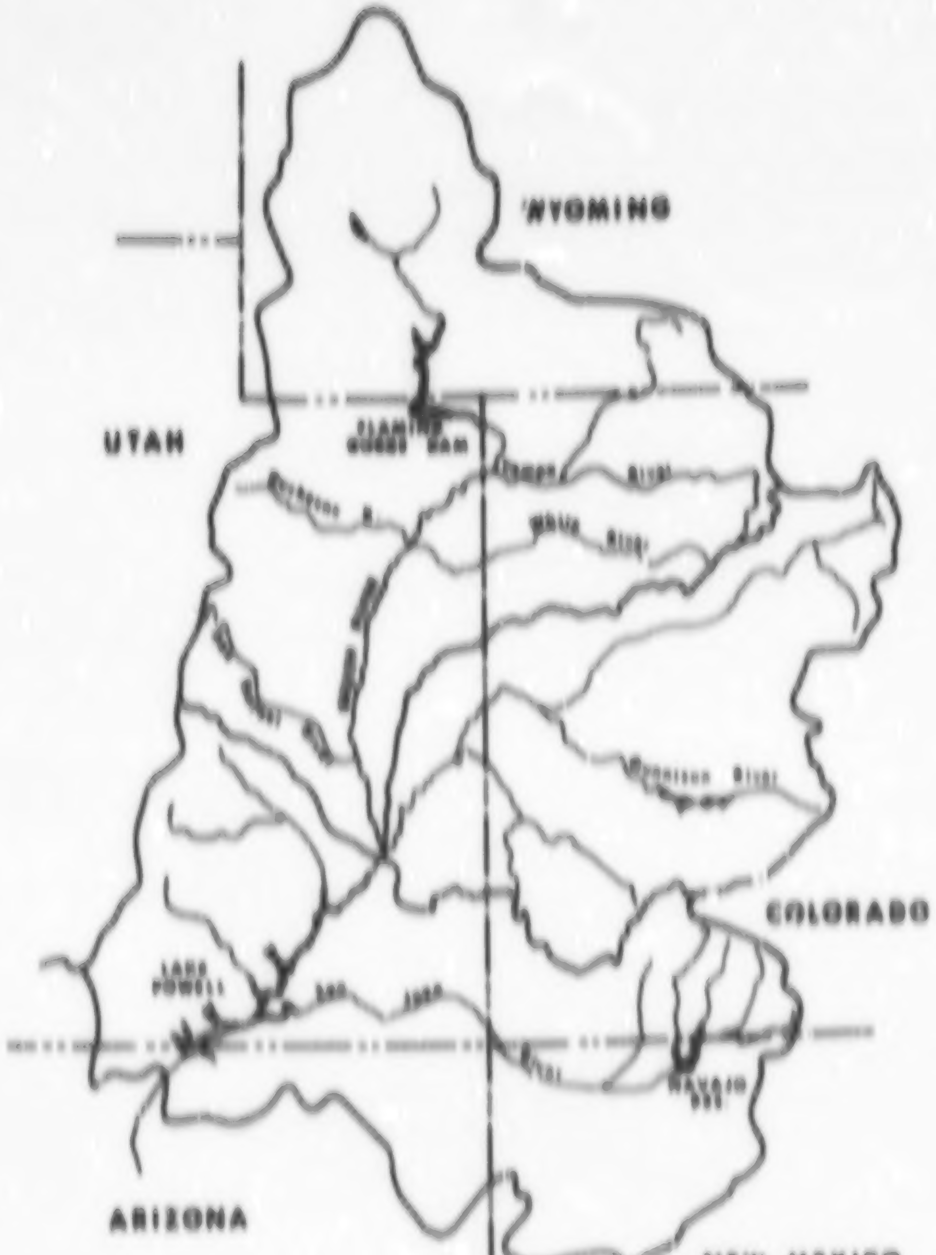

FIGURE 12-1: UPPER COLORADO RIVER BASIN

acre-ft/yr would be available for consumptive use if 7.5 million acre-ft/yr were delivered to the Lower Basin and Upper Basin users did not have to experience any shortages.

3. The Lake Powell Research Project estimated that 5.25 million acre-ft/yr are available for consumptive use if 8.25 million acre-ft/yr are delivered to the Lower Basin.[1]

In our analysis, 5.8 million acre-ft/yr was used, although for impacts which are particularly dependent on flow rate, the effects of using one of the other values are noted.

Estimates of the quantities of water currently being consumed in the UCRB also vary, primarily because of the inconsistent depletion categories used by various studies. Table 12-14 gives values for 1974 depletions totaling 3.707 million acre-ft/yr;[2] using different assumptions, another study estimated 1975 depletions to be 3.101 million acre-ft/yr.[3]

Irrigation of agriculture accounted for 58 percent of the 1974 depletion. Interbasin transfers, the largest of which was to the Denver area, consumed 20 percent, and evaporation losses accounted for 14 percent. Other uses were negligible compared to these.

Water quality in the UCRB has been studied extensively. The principal water quality problem is salinity. The average annual salt flow at Lee Ferry has been estimated at 8.6 million tons, of which 4.3 million tons are from natural sources, 1.5 million

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[1] Weatherford, Gary D., and Gordon C. Jacoby. "Impact of Energy Development on the Law of the Colorado River." *Natural Resources Journal*, Vol. 15 (January 1975), pp. 171-213.

[2] U.S., Department of the Interior, Water for Energy Management Team. *Report on Water for Energy in the Upper Colorado River Basin*. Denver, Colo: Department of the Interior, 1974, p. 13.

[3] U.S., Department of the Interior, Bureau of Reclamation. *Westwide Study Report on Water Problems Facing the Eleven Western States*. Washington, D.C.: Government Printing Office, 1975.

TABLE 12-24: ESTIMATED 1974 DEPLETIONS
(thousands of acre-feet per year)

	Arizona	Colorado	Utah	Wyoming	New Mexico	Total	Depletion
Thermal power plants	a	9	1	3	25	38	1.0
Food and fiber (irrigation)	10	1,255	529	250	102	2,152	59.1
Fish, wildlife, and recreation[b]	3	31	24	16	6	80	2.1
Minerals and mining		17	9	18	4	48	1.3
Livestock ponds and evaporation		21	6	27[c]	25[d]	79	2.1
Municipal and industrial		18	6	3	8	35	1.0
Exports		504	130	30	110	754	20.3
Subtotal	13	1,855	705	329	286	3,137	
Main stem reservoir losses	0	269	120	73	58	520	14.0
Total depletion	13	2,124	825	402	344	3,657	

Source: U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974, p. 131.

[a] First unit of Navajo Power Plant went on line in May of 1974. Actual depletion amount not available.

[b] Natural historic wildlife consumption not included.

[c] Includes evaporation from Fontenelle Reservoir.

[d] Includes evaporation from Navajo Reservoir.

tons from agricultural uses, and 2.8 million tons from other manmade sources.[1] A detailed description of the natural sources of salinity is included in several reports.[2] According to the classification system used by the U.S. Geological Survey (USGS), water with a salt or total dissolved solids (TDS) content of up to 1,000 milligrams per liter (mg/ℓ) is considered fresh. The EPA Interim Primary Drinking Water Standard has no TDS limit;[3] however, the EPA proposed secondary standard recommends that TDS be limited to 500 mg/ℓ.[4] For livestock, water is rated good up to a TDS of 2,500 mg/ℓ.[5]

The more saline the water, the less desirable it is for agricultural purposes as well as for drinking. Concentrations of TDS at various points in the UCRB are shown in Table 12-15. All the streams are fresh according to the USGS classification system, except for the San Rafael River which flows through extensive salt and potash deposits in Utah.

The allocation of water rights and the legal/political problems surrounding them will be important in determining whether a portion of the unused water in the UCRB can be used for energy developments. (These problems and associated issues are discussed in Chapter 14.)

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[1] Hyatt, M. Leon, et al. Computer Simulation of the Hydrologic-Salinity Flow System Within the Upper Colorado River Basin. Logan, Utah: Utah State University, Utah Water Research Laboratory, 1970. Other studies differ in their breakdown of sources but appear to agree on total load in the river.

[2] Williams, J. Stewart. The Natural Salinity of the Colorado River, Occasional Paper 7. Logan, Utah: Utah State University, Utah Water Research Laboratory, 1975; and U.S., Department of the Interior, Bureau of Reclamation, Water Quality Office. Quality of Water--Colorado River Basin, Progress Report No. 7. Denver, Colo.: Bureau of Reclamation, 1975.

[3] U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." 40 Fed. Reg. 59,566-88 (December 24, 1975).

[4] U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17,143-47 (March 31, 1977).

[5] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. II-152.

TABLE 12-15: AVERAGE DISSOLVED SOLIDS CONCENTRATIONS IN STREAMS OF THE UPPER COLORADO REGION, 1941-1972

Station Location	Total Dissolved Solids (mg/l)
Green River Subregion	
Green River at Green River, Wyoming	307
Green River near Greendale, Utah	421
Green River at Green River, Utah	456
Duchesne River near Randlett, Utah	680
San Rafael River near Green River, Utah	1,688
Upper Main Stem Subregion	
Colorado River near Glenwood Springs, Colorado	270
Colorado River near Cameo, Colorado	405
Colorado River near Cisco, Utah	612
Gunnison River near Grand Junction, Colorado	621
San Juan-Colorado Subregion	
San Juan River near Archuleta, New Mexico	159
San Juan River near Bluff, Utah	447
Upper Colorado Region Outlet	
Colorado River at Lee Ferry, Arizona	558

mg/l = micrograms per liter

Source: Abstracted from, U.S., Department of the Interior, Bureau of Reclamation, Water Quality Office. Quality of Water--Colorado River Basin, Progress Report No. 7. Denver, Colo.: Bureau of Reclamation, 1975.

The legal structure governing the Colorado River has developed over more than 50 years. Major compacts include the Colorado River Compact, which apportioned the flow between the Upper and Lower Basins and guaranteed 7.5 million acre-feet per year (acre-ft/yr) to the Lower Basin. The Upper Colorado River Basin Compact[1] divided the flow available to the Upper Basin, giving 50,000 acre-ft/yr to Arizona and apportioning the remainder as 51.75 percent to Colorado, 11.25 percent to New Mexico, 23 percent to Utah, and 14 percent to Wyoming.

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[1] Upper Colorado River Basin Compact of 1948, 63 Stat. 31 (1949).

The Mexican Water Treaty of 1944 guarantees Mexico 1.5 million acre-ft/yr from the Colorado River[1] but does not specify whether this amount should come equally from the Upper and Lower Basin apportionments or all from the Lower Basin. In addition, an agreement with Mexico in 1973[2] and the Colorado River Basin Salinity Control Act of 1974[3] address salinity problems in the basin.

Water quality standards for the Colorado River have been set by the states of the basin at 723 mg/ℓ below Hoover Dam, 747 mg/ℓ below Parker Dam, and 879 mg/ℓ at Imperial Dam.[4]

2. Groundwater

Large quantities of groundwater are present in the UCRB. Although its distribution and quality is largely a function of geology and topography, UCRB groundwater is generally more evenly distributed than surface water and has a higher TDS. The most important groundwater aquifers are in sedimentary bedrock and in the alluvium of sand and gravel along rivers and streams. An estimated 115 million acre-ft/yr of water is stored in these aquifers at a depth of less than 100 feet,[5] with substantially greater quantities in deeper reservoirs. This quantity is almost four times the storage capacity of all surface water reservoirs in the basin. The rate of recharge is about 4 million acre-ft/yr, but because many groundwater aquifers are isolated, the rate of withdrawal locally without mining must be determined from local recharge rates. Wells capable of yielding as much as 1,000 gallons per minute (gpm) can be drilled in much of the basin.[1]

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[1] Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

[2] International Boundary and Water Commission. "Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River," Minute No. 242. *Department of State Bulletin*, Vol. 69 (September 24, 1973), pp. 395-96.

[3] Colorado River Basin Salinity Control Act of 1974, Pub. L. No. 93-320, 88 Stat. 266 (codified at 43 U.S.C.A. §§1571 *et seq.* (Supp. 1976).

[4] Fed. Reg. 13,656-57 (March 31, 1976). Colorado agreed to the standards at a later date.

[5] Price, Don, and Ted Arnow. *Summary Appraisals of the Nation's Ground-Water Resources--Upper Colorado Region*. U.S. Geological Survey Professional Paper 813-C. Washington, D.C.: Government Printing Office, 1974.

Flow into groundwater aquifers usually takes place at high elevations where precipitation and flow in surface streams is greatest and where the layers of rock making up the aquifer crop out at the surface. Discharge from the aquifers occurs at lower elevations in springs, seeps, and back into surface streams. Because of the slow movement of water in the aquifer, its behavior is much like that of a surface impoundment. With a continuous discharge, this can be beneficial to maintaining flow in surface streams during periods of normal low flow.

Water quality in aquifers in the UCRB varies widely but in general is a function of the mineral composition of the aquifer and the length of time the water has been stored there. Thus, water close to the recharge area (at higher elevations) has the best quality, and quality decreases at lower elevations. Water in aquifers above 7,000 feet elevation generally has a TDS of less than 1,000 mg/ℓ.[2] (This is fresh water according to the USGS classification system.)

About 133,000 acre-ft/yr of groundwater are currently used in the UCRB.[3] In the basin, this is 2 percent of the total water used[4] and about 3 percent of the annual recharge rate for groundwater. Groundwater use is primarily limited by inadequate knowledge of where it is located and what its quality is. Use is also limited because the slow movement of water in aquifers requires a large number of wells over a wide area to withdraw substantial amounts in relatively short periods. (If a sufficiently large groundwater aquifer could be found, 25 wells would be required, each producing 1,000 gpm, to supply water to a 3,000-megawatt electrical power plant.) Obtaining rights to groundwater is also difficult because use is generally administered locally rather than on a statewide or regional basis. This situation is changing as demand for water increases. (See Section 14.2)

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[1] U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 35.

[2] Price, Don, and Ted Arnow. Summary Appraisals of the Nation's Ground-Water Resources--Upper Colorado Region. U.S. Geological Survey Professional Paper 813-C. Washington, D.C.: Government Printing Office, 1974.

[3] U.S., Department of the Interior. Westwide Study.

[4] Price and Arnow. Ground-Water Resources--Upper Colorado Region.

B. Water Requirements

The water requirements for energy development in the UCRB have been calculated for the three levels of energy development postulated in Section 12.1.[1] These requirements are shown in Table 12-16. Requirements will vary with the technologies used. If water minimization techniques are employed for all uses except cooling, regional consumption for the year 2000 could be reduced by between 18 and 22 percent, or between 162,000 and 185,000 acre-ft/yr[2] depending on the level of development. Using wet-dry or dry cooling could reduce these requirements even further but at a higher economic cost.[3]

Water requirements resulting from the increases in population associated with the three levels of development have been projected and are shown in Table 12-17. Assuming a daily consumption of 150 gallons per person, these water requirements will be less than 56,000 acre-ft/yr. This is approximately the amount of water required for two steam-electrical power plants. Thus, population water requirements will be small compared to those for the facilities themselves, and will remain small, even if the per-capita consumption doubles from the 150 gallons assumed.

Total water requirements for the UCRB in the year 2000 for the three levels of development assumed in Section 12.1 are: Low Demand case, 798,000 acre-ft/yr; Nominal Demand case, 1,015,900 acre-ft/yr; and Low Nuclear Availability case, 1,093,600 acre-ft/yr.

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[1] The location of the water demand is of some importance in the evaluation of the effects of demand on the water system. In this report, the regional demands are not addressed with respect to a specific site but rather with respect to the basin as a whole.

[2] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[3] The water consumption and economic consequences of cooling alternatives will be evaluated during the remainder of this study. Cursory examination of the data indicates that dry cooling systems would cost 1.28 times as much as wet-dry systems, and 2.20 times as much as wet-dry systems. See, for example, Heller, Laslo. "Heller Discusses Hybrid Wet/Dry Cooling." Electrical World, Vol. 179 (March 15, 1973), pp. 74-77.

TABLE 12-16: PROJECTED WATER DEMAND UPON THE UPPER COLORADO RIVER BASIN FOR ENERGY DEVELOPMENT[a]

	Water Requirements (acre-feet per year)								
	Low Demand			Nominal Demand			Low Nuclear Availability		
Energy Type	1985	1990	2000	1985	1990	2000	1985	1990	2000
Coal Mines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Slurry Pipelines	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
Gasification	0	0	[illegible]	0	0	[illegible]	0	0	[illegible]
Liquefaction	0	0	0	0	0	0	0	0	0
Power Plants	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oil Shale	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
Uranium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Taken from Section 12.1, SRI Model regional demand predictions, and from the Energy Resource Development System descriptions, assuming that the following facility water requirements hold:

Facility	Assumed Size	Load Factor	Water Requirements (acre-feet per year)
Coal Mine	5 million tons per year	100%	[illegible]
Slurry Pipeline	25 million tons per year	100%	[illegible]
Coal Gasification	250 million cubic feet per day	90%	[illegible]
Coal Liquefaction	100,000 barrels per day	90%	[illegible]
Power Plant	3,000 megawatts-electric	70%	[illegible]
Oil Shale Retort	100,000 barrels per day	90%	[illegible]
Uranium Mill	[illegible] tons per year	100%	[illegible]

TABLE 12-17: WATER REQUIREMENTS FOR POPULATION INCREASES IN THE UPPER COLORADO RIVER BASIN[a,b] (acre-feet per year)

	Low Demand				Nominal Demand				Low Nuclear Availability			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Colorado	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New Mexico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Above the value consumed in [illegible].

[b] Assuming [illegible] gallons per capita per day and using population increase estimates from Section [illegible] for the [illegible] discussed in Section [illegible].

C. Water-Related Impacts of Energy Development in the UCRB

1. Surface Water

The most obvious impact of energy development in the UCRB will be the withdrawal of water to supply the energy conversion facilities. As noted above, basinwide water requirements for the three levels of development would range from 795,000 to 1,094,000 acre-ft/yr by 2000. Using 1974 depletion levels, and assuming the Water for Energy Management Team's estimate of 5.8 million acre-ft/yr available to the Upper Basin is correct, the Upper Basin states are entitled to approximately 2.1 million acre-ft/yr of surface water which is not now being used in the Upper Basin. The energy developments postulated in our scenarios would require between 38 and 71 percent of this water.[1] In addition, water will be required for secondary industrial and agricultural uses occurring as a direct result of the energy developments, as well as growth occurring independent of energy development.

Depending on how the demands for water are divided among the rivers in the UCRB and how reservoirs are used to regulate flow, flow depletion could become a problem as a result of energy withdrawals. Table 12-10 shows requirements disaggregated to various river basins for the year 2000. In all cases, the total energy-related demand is well below the average flow. However, the demands are a large fraction of typical low flows and equal or exceed record low flows. These water requirements and the resulting flow reductions which could occur during low flow periods could impact several threatened fish and waterfowl species. (These impacts are discussed in Section 12.5.2.)

The water requirements for energy development described above will also affect water quality. Unless desalinization is carried out, current TDS values should increase significantly as a result of development in the UCRB. Even assuming no return flows from energy facilities, salt concentration will increase because of the withdrawal of diluting water upstream of the principal sources of salt loadings. For example, increases of 3 mg/l were expected at Imperial Dam as a result of the Kaiparowits project alone.[2] If desalinization projects are not carried out, increases in salinity at Imperial Dam are projected to increase

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[1] To deal with water availability problems, both interbasin transfers and weather modification have been proposed as ways of augmenting present supplies. See Section 14.2 on Water Policy.

[2] U.S., Department of the Interior, Bureau of Land Management. _Final Environmental Impact Statement: Proposed Kaiparowits Project_, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. III-157.

TABLE 12-18: INDUSTRIAL WATER DEMAND VERSUS SUPPLY FOR SELECTED RIVER BASINS[a]

Subarea	Nominal Demand for Sub-area (Year 2000)[b]	Major Surface Water Source	Average Flow	Low Flow of Record	Minimum Flow[c]
Four Corners	64,000 acre-ft/yr (88 cfs)	San Juan River at Farmington	1,810,000 acre-ft/yr 2,500 cfs	15 cfs	100-300 cfs
		San Juan River at Shiprock	1,664,000 acre-ft/yr 2,300 cfs	9 cfs	40-200 cfs
West Colorado	647,256 acre-ft/yr (894 cfs)	Colorado River near Cameo	2,821,000 acre-ft/yr 3,900 cfs	700 cfs	800-1300 cfs
	66,800 acre-ft/yr (92 cfs)	White River near Meeker	455,400 acre-ft/yr 630 cfs	112 cfs	170-210 cfs
East Utah	66,600 acre-ft/yr (92 cfs)	Green River near Jensen	3,106,000 acre-ft/yr 4,290 cfs	182 cfs	250-400 cfs

cfs = cubic feet per second

[a] Data from U.S., Department of the Interior, Geological Survey. Surface Water Supply of the U.S., 1961-65, Part 9, Colorado River Basin, Vols. 1 and 2, Water Supply Papers 1924 and 1925. Washington, D.C.: Government Printing Office, 1970; and U.S., Department of the Interior, Geological Survey. Surface Water Supply of the U.S., 1966-70, Part 6, Missouri River Basin, Vol. 1, Water Supply Paper 2116. Washington, D.C.: Government Printing Office, 1974.

[b] Demand assuming the Nominal SRI Case for the year 2000 (see Section 12.1); water requirements for the technologies from the Energy Resource Development System Descriptions and attributed to the nearest surface water supply to the resource location.

[c] The range represents the minimum flows that occurred during 1961-1965.

from the present level of 875 mg/ℓ to as high as 1,250 mg/ℓ in the the year 2000.[1] This will be in violation of the limit established by the states under the Federal Water Pollution Control Act; hence, additional salinity control measures, such as those authorized by the Salinity Control Act of 1974,[2] will be required. The economic costs of damages due to increases in salinity at Imperial Dam have been estimated at $230,000 per mg/ℓ of TDS increase,[3] primarily because of decreased crop production from lands irrigated with this water. Control of salt loadings through irrigation management and other on-farm measures has been estimated at between $7,000 and $750,000 per mg/ℓ, and desalinization plants would cost between $100,000 and $4,000,000 per mg/ℓ at Imperial Dam.[4]

Although the most severe water-related impacts in the UCRB will be due to water availability and increases in salinity, a number of additional impacts will also be important. Most of these impacts are discussed in the site-specific chapters, and those chapters should be read for specific details. Problems and issues resulting from these impacts are discussed in Section 14.2.

Many small western communities will experience municipal and industrial water supply problems. Since many municipal supplies are drawn from groundwater sources, these problems will be closely related to groundwater usage and quality.

Municipal and industrial wastewater treatment facilities may become overloaded in areas of rapid population growth, resulting in discharges of inadequately treated or untreated waste. Packaged plants, aerated ponds, and other expedient wastewater treatment methods can be used but at increased cost to the municipality (see Section 14.7).

Currently, in-stream water needs to support fish and wildlife are receiving attention by the Fish and Wildlife Service, and these needs will affect water availability. (The impacts of inadequate in-stream flow on ecology are discussed in Section 12.5.)

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[1] Utah State University, Utah Water Research Laboratory. Colorado River Regional Assessment Study, Part 1, Executive Summary, Basin Profile and Report Digest, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975, p.26.

[2] Colorado River Basin Salinity Control Act of 1974, Pub.L. No. 93-320, 88 Stat. 266 (codified at 43 U.S.C.A. §§ 1571 et seq. (Supp. 1976).

[3] Utah Water Research Laboratory. Colorado River Regional Assessment Study, p. 3.

[4] Ibid, p. 5.

Because some of the areas of most interest for energy development have been sparsely populated, few hydrologic data have been collected for those areas. These data are needed to permit planning for growth in water demands, and the USGS and state agencies are attempting to collect this data.

The discharge of effluents from energy facilities will have an effect on the quality of surface water. The extent of impacts will depend on the quantity of effluents, the methods used for disposal, and the composition of effluents. Some form of lined holding ponds will be necessary to protect the quality of adjacent surface and groundwaters; however, pond design experience is generally not available in this region and thus pond failures and resultant pollutant migration are likely.[1]

2. Groundwater

The quantity and quality of groundwater in the UCRB should decrease as a consequence of energy development. Both impacts will result from withdrawals from and additions to water in aquifer systems.

A. Groundwater Quantity Impacts

Groundwater withdrawals from aquifer systems are expected to increase significantly as a consequence of levels of energy resource development called for in our eight-state area scenario. Most of these withdrawals will be to meet either facility or population needs, but some withdrawals may also be necessary to dewater mines. Groundwater sources may be an important supplement to surface-water supplies for meeting the requirements of energy conversion facilities, but most groundwater will be used for supplying municipal and rural population needs. Groundwater is especially attractive as a water source for domestic supplies in a water-short area like the UCRB. At present, about 31,600 acre-ft/yr are withdrawn for municipal supplies and about 14,000 acre-ft/yr are used for domestic supplies in rural areas.[2] About 4,300 acre-ft/yr are currently used for cooling in power plants.

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[1] See Smith, E.S. "Tailings Disposal--Failures and Lessons," in Aplin, C.L., and G.O. Argall, eds. *Tailing Disposal Today*. San Francisco, Calif.: Miller Freeman, 1973, p. 358.

[2] U.S., Department of the Interior, Bureau of Reclamation. *Westwide Study Report on Water Problems Facing the Eleven Western States*. Washington, D.C.: Government Printing Office, 1975, p.51.

Large-scale groundwater withdrawals could lead to both local and regional lowering of the water levels in aquifers in the immediate vicinity of wells. Lowered water levels could cause wells, springs, and seeps to go dry and could result in lower base flows in streams and rivers. The close interrelationship between groundwater and surface water could result in disputes over water rights stemming from groundwater withdrawals.

Mining may affect local groundwater systems in several ways. Both underground and surface mines can interrupt aquifer flow, making dewatering operations necessary. As much as 1,100 square miles or almost 1 percent of the total surface area of the UCRB may be subjected to surface mining(Table 12-19). Depending on the composition of the overburden, oxidation may release contaminants to local shallow groundwater systems. In areas where the energy resource is also an aquifer, as coal strata sometimes are, the aquifer will be destroyed when the resource is mined. If the overburden is an aquifer, the aquifer properties may be greatly altered when the overburden is removed and then replaced. Reclaiming surface mined lands for surface uses will not restore the aquifer properties. Mixing materials may reduce porosity and permeability, but this tendency may be offset by the disaggregation and loosening of materials during removal and replacement.

TABLE 12-19: SURFACE ACREAGE ULTIMATELY DISTURBED BY MINING IN THE UPPER COLORADO RIVER BASIN (acres)[a]

Location	Low Demand Case	Nominal Case	Low Nuclear Availability Case
Western Colorado[b]	39,900	47,600	79,400
Southwest Deserts[c]	68,900	121,900	177,000

[a] Based on the number of mines hypothesized in the SRI model (see Section 12.1), a coal density of 85 pounds per cubic foot, and seam thicknesses given below.

[b] Includes Rio Blanco, Garfield, and Huerfano Counties, assuming one-third of the projected mines are underground and an average seam thickness of 7 feet.

[c] Includes San Juan County, New Mexico, with an assumed average seam thickness of 10.0 feet and Kane and Garfield Counties, Utah, assuming half the projected mines are underground and an average seam thickness of 10 feet.

The net effect will vary according to the geologic conditions and will have to be evaluated on a case-by-case basis.

B. Groundwater Quality Impacts

Most of the groundwater quality degradation that will result from energy development will be caused by additions to the natural aquifer systems. Shallow aquifers may be polluted locally by mines, by energy conversion facilities, and by facilities associated with population growth. Deep aquifers would generally be polluted only where deep-well injection is used as a means of liquid waste disposal.

Contaminated water from energy conversion facilities may enter groundwater systems directly as a result of seepage of liquid wastes and indirectly from leaching of solid waste from disposal sites. The type of pollutant will vary from facility to facility, depending on the type of conversion process and the composition and quantity of waste generated. Estimates of the amount of waste generated for the conversion processes considered are presented in Table 12-20. Problems and issues related to holding ponds disposal of effluents are discussed in Section 14.2.3.

In most places in the UCRB, the bedrock between the surface and the water table is mostly sandstone and shales which can filter and absorb contaminated seepage. In addition, the water table in bedrock aquifers is quite deep, which also reduces the chances for contamination. In alluvial aquifers, the unconsolidated sand, gravel and clay can similarly filter and absorb contaminants.

Population growth associated with the projected energy development of the scenario will have two principal impacts on groundwater systems: the withdrawals required for municipal and domestic supplies, and the liquid and solid waste disposal methods used. Where large developments are built over small or low-permeability aquifers, water levels may decline as a result of excessive withdrawal. Since the soils in much of the UCRB are thin, the effluent from septic tank drainfields, where used, may not be fully renovated, and partially-treated effluent may seep into local groundwater. Pollutants leached from solid waste disposal sites could also contaminate shallow aquifers, but the arid climate over most of the basin lessens the potential seriousness of this problem.

TABLE 12-20: WATER CONSUMED AND RESIDUALS GENERATED FOR STANDARD-SIZE PLANTS IN EACH STATE OF WESTERN REGION[a]

State	Slurry Pipeline 25×10^6 tpy at 100% load factor		Lurgi Gas 250×10^6 scf/stream-day at 90% load factor		Synthane Gas 250×10^6 scf/stream-day at 90% load factor	
	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy
Montana	19,171	–	4,618	1.27	7,800	1.22
North Dakota			3,307	1.20	7,671	1.30
Wyoming	19,171	–	4,286	0.72	7,776	0.71
Colorado	19,171	–				
New Mexico			5,639	3	8,670	2.06
Utah						

State	Synthoil 100,000 bbl/stream-day at 90% load factor		Electrical Generation 3,000 MWe at 35% efficiency and 70% load factor		Oil Shale 100,000 bbl/stream-day at 90% load factor	
	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy	Acre-Ft/yr[b]	Wet Solids[c] 10^6 tpy
Montana	10,296	2.07	26,659	3.01		
North Dakota	10,085	2	22,084	2.65		
Wyoming	9,227	1.23	25,842	1.32		
Colorado			28,482	1.74	12,930	40.65
New Mexico	11,753	5.31	29,205	5		
Utah			29,824	5.30	12,524	40.85

bbl = barrels
MWe = megawatt-electric
scf = standard cubic feet
tpy = tons per year

Source: Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[a] These quantities for each state are the unit values used in each energy scenario. For example, if the scenario were to have three Lurgi plants in Montana and two in Wyoming, the Lurgi water requirements would be 3 x 4,618 acre-ft/yr in Montana, and 2 x 4,286 acre-ft/yr in Wyoming.

[b] Water consumed.

[c] Wet solids.

12.3.2 Upper Missouri River Basin

A. Existing Conditions

1. Surface Water

Surface water is available from several sources in the Upper Missouri River Basin (UMRB). As shown in Figure 12-2, the major sub-basins are the Upper Missouri, Yellowstone, Western Dakota Tributaries, and Eastern Dakota Tributaries. The major tributaries to the Missouri are the Yellowstone, Powder, Little Missouri, Cheyenne, Belle Fourche, and James Rivers. Flows are generally highest in the western part of the basin as a result of melting snow and ice in the spring, and can also be high throughout the basin as a result of prolonged rainfall or summer cloudbursts.

Major river flows in the Fort Union Coal Region of the UMRB are shown in Table 12-21. The 8.8 million acre-ft/yr in the Yellowstone contributes about half the total flow into the Missouri above Lake Sakakawea. Water supply and use in the Montana and Wyoming portions of the UMRB are shown in Table 12-22 for 1975. Total depletions are only 16 percent of the 20 million acre-ft/yr available in Montana and 19 percent of the nearly 8 million acre-ft/yr available in Wyoming. Data on categories of depletions for the Fort Union region of the UMRB in North Dakota are not available.

The total average depletion in the UMRB is not well documented, but is about 6.5 million acre-ft/yr including reservoir evaporation above Sioux City, Iowa.[1] The undepleted flow at that point is approximately 28.3 million acre-ft/yr of which 19 million acre-ft/yr are estimated to be the practical limit for depletions.[2] Hence, at present, 12.5 million acre-ft/yr are apparently available for use.

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[1] Northern Great Plains Resources Program, Water Work Group Report, Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974, p. 16.

[2] U.S., Department of the Interior, Water for Energy Management Team, Report on Water for Energy in the Northern Great Plains Areas with Emphasis on the Yellowstone River Basin, Denver, Colo.: Department of the Interior, 1975, p. VII-6.

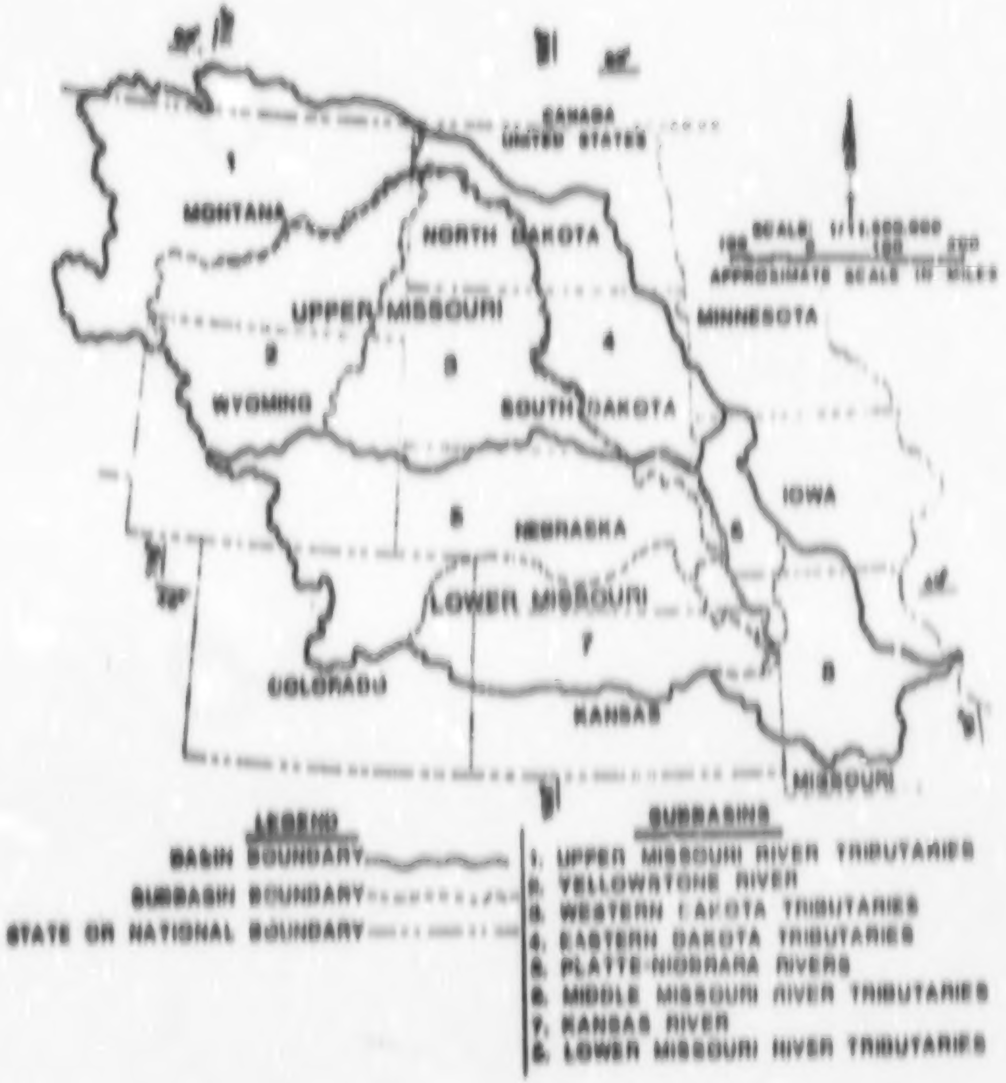

FIGURE 12-2: SUBBASINS OF THE MISSOURI RIVER BASIN

TABLE 12-21: FLOW IN MAJOR STREAMS IN THE FORT UNION COAL REGION OF THE UPPER MISSOURI RIVER BASIN[a]

River and Location	Maximum Annual Flow (acre-feet)	Minimum Annual Flow (acre-feet)	Average Annual Flow (acre-feet)
Yellowstone Basin			
Clarks Fork Yellowstone	1,120,000	538,000	767,000
Wind-Bighorn near mouth	3,667,000	1,429,000	2,550,000
Tongue near mouth	569,000	32,000	304,090
Powder near mouth	1,154,000	43,000	426,000
Yellowstone near Sidney	12,690,000	3,720,000	8,800,000
Western Dakota Tributaries			
Little Missouri near mouth	1,294,000	35,000	390,000
Knife near mouth	315,000	3,000	118,000
Heart near mouth	515,000	17,000	154,000
Cannonball near mouth	711,000	1,000	149,000
Grand near mouth	712,000	9,000	156,000
Missouri River at Lake Sakakawea	-	-	16,952,000
Missouri River at Oahe Reservoir	-	-	18,525,000
Missouri River at Sioux City, Iowa	-	-	28,300,000[b]

[a] Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S. Department of the Interior, Bureau of Reclamation, 1974, p. 13.

[b] U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. VII-6.

TABLE 12-22: WATER SUPPLY AND USE IN THE UPPER MISSOURI
(1,000 acre-feet per year)

	Montana	Wyoming
Total Water Supply[a]	20,141	7,884
Estimated depletions[a]		
Irrigation	2,280	1,245
Municipal and industrial	99	29
Minerals and mining	10	55
Thermal electric	1	3
Other	204	
Reservoir Evaporation	603	172
Total Depletions	3,197	1,504

Source: U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, pp. 229, 300, 411, 412.

[a] Water supply and depletion estimates are only for the Upper Missouri portion of the states. The states include portions of other river basins as well.

Water quality in the UMRB is generally good. Table 12-23 gives concentrations of TDS at selected locations in the Fort Union Coal Region. The Missouri at Bismarck and the Yellowstone at its mouth both have TDS of less than 450 mg/ℓ, and only the Powder River has a TDS much greater than that considered fresh by the USGS classification system.

The allocation of water rights and the legal/political problems surrounding them are important in determining whether a portion of the unused water of the Yellowstone and other rivers in the UMRB can be used for energy purposes. (These problems and associated issues are discussed in Section 14.2.) The legal structure governing the Upper Missouri River is not as detailed as that for the Colorado, partly because much more water is available and not being used.

TABLE 12-23: WATER QUALITY OF SELECTED RIVERS IN THE FORT UNION COAL AREA OF THE UPPER MISSOURI RIVER BASIN[a]

River	TDS (mg/ℓ)
Bighorn River at Bighorn, Montana	613
Tongue River at Miles City, Montana	496
Powder River at Moorhead, Montana	1,226
Yellowstone River at Miles City, Montana	396
Missouri River at Bismarck, North Dakota	441

mg/ℓ = milligrams per liter

[a] Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S. Department of the Interior, Bureau of Reclamation, 1974, p. 62.

Interstate compacts exist for two rivers in the UMRB important for energy resource development, the Yellowstone and the Belle Fourche. The Belle Fourche River Compact[1] apportions the unappropriated water of the river 90 percent to South Dakota and 10 percent to Wyoming. The Yellowstone River Compact[2] apportions the waters of the Yellowstone and its tributaries between Montana and Wyoming as follows:

Tributary	Wyoming (percent)	Montana (percent)
Clarks Fork	60	40
Bighorn	80	20
Tongue	40	60
Powder	42	58

Based on these allocations and estimates of annual flow and present consumption on the Belle Fourche and Yellowstone, estimates have been made of unappropriated flow available to the states involved. These are shown in Table 12-24. The flow in the Yellowstone basin available to Wyoming is estimated at 2.44 million acre-ft/yr; that available to Montana is estimated at 1 million acre-ft/yr.

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[1] Belle Fourche River Compact of 1943, 58 Stat. 94 (1944).

[2] Yellowstone River Compact of 1950, 65 Stat. 663 (1951).

TABLE 12-24: ALLOCATION OF FLOWS BY INTERSTATE WATER COMPACTS FOR STREAMS WITHIN THE FORT UNION COAL REGION[a]

Compact	Stream	Average Annual Flow[b] (acre-ft/yr)	Unappropriated Flow[c] (acre-ft/yr)	Unappropriated Flow Available to States[c] (acre-ft/yr)		
				Wyoming	Montana	South Dakota
Yellowstone River	Powder River	426,000	287,300	120,000	166,600	-
	Tongue River	304,000	241,000	96,400	144,700	-
	Bighorn River	2,500,000	2,200,000	1,800,000	400,000	-
	Clarks Fork	767,000	714,000	429,000	285,300	-
Belle Fourche	Belle Fourche River	184,000	87,000	7,300	-	79,700

[a] Taken from U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, pp. II-5.

[b] Historic average annual flow adjusted to the 1970 level of development.

[c] Wyoming, State Engineer's Office, Water Planning Program. Water and Related Land Resources of Northeastern Wyoming. Report No. 10. Cheyenne, Wyo.: Wyoming Water Planning Program, 1972.

2. Groundwater

Aquifers in the UMRB include both deep and shallow aquifers in the bedrock as well as shallow aquifers in the alluvium above the bedrock. A total of about 860 million acre-ft of water is stored in these aquifers at a depth of less than 1,000 feet.[1] The aquifers most likely to affect or be affected by our hypothesized energy developments are the Madison (which extends to several thousand feet in depth), several aquifers in the Fort Union Coal formation (which are less than a hundred feet deep), and alluvial aquifers associated with the major rivers and streams. The shallow bedrock and alluvial aquifers are not productive enough to be considered as potential sources of water for energy facilities,[2] but they will probably be used extensively to supply water for the associated population growth. If groundwater is used to help meet the demands of the energy conversion facilities, the Madison aquifer is the most likely source.

The Madison aquifer is presently being studied as a possible water source for energy developments, although its hydrogeology is not completely understood.[3] Some wells into the aquifer yield more than 10,000 gpm, but most yield less than 1,000 gpm.[4] The Madison is recharged at high elevations where the limestone forming the aquifer crops out. High elevation rainfall and snowmelt are the primary sources of the water. Discharge from the Madison is to wells and, via leakage, into shallower aquifers. The quality of water in the Madison, as measured by TDS, ranges from less than 500 mg/l near the recharge areas in the Powder River Basin to more than 4,000 mg/ℓ near the Montana-North Dakota line.[1] In the Williston Basin area, where the water has been in the aquifer much longer, it is moderately to very saline (3,000-10,000 mg/ℓ) and therefore not as likely to be used for energy facilities in the lignite fields of western North Dakota. Existing uses of Madison groundwater are for municipal, industrial, domestic, stock, and oil field waterflood purposes.[2]

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[1] Missouri Basin Inter-Agency Committee. *The Missouri River Basin Comprehensive Framework Study*. Denver, Colo.: U.S., Department of the Interior, Bureau of Land Management, 1971, Vol. 1, p. 63.

[2] Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. *Water Resources Problems Related to Mining. American Water Resources Association Proceedings*, Vol. 18 (1974), p. 212.

[3] Swenson, Frank A. *Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming*. Denver, Colo.: Northern Great Plains Resources Program, 1974.

[4] U.S., Department of the Interior, Geological Survey. *Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming*, Open-File Report 75-631. Denver, Colo.: Geological Survey, 1975, p. 3.

Aquifers in the Fort Union Formation occur in both sandstone beds and coal seams. They are recharged from precipitation in high elevation areas and from surface streams. Most of these aquifers are at or near the water table depth. Water quality in Fort Union aquifers varies depending on rock composition and how long the water has been in the aquifer. Existing uses are primarily for rural domestic supplies and stock watering.

Alluvial aquifers are located below major rivers and streams in the basin. The total amount of water stored in these aquifers is not known, but the productivity of some is sufficient to supply irrigation wells that produce over 1,000 gpm. Water quality in alluvial aquifers is usually good unless recharge is from lower bedrock aquifers. Existing uses include supplying water for municipal, domestic, stock, and irrigation needs.

Groundwater use in the UMRB is limited by the large number of wells usually needed to produce high yields, the low permeability of the aquifers which limits the flow per well, and the lack of sufficient knowledge on the occurrence, location, and properties of the aquifers.

B. Water Requirements

The water requirements for energy development in the UMRB have been calculated for the three levels of energy development postulated in Section 12.1. These requirements are shown in Table 12-25. Requirements will vary with the technologies used. If water minimization techniques are employed for all uses except cooling, regional consumption for the year 2000 could be reduced

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[1] Swenson, Frank A. *Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming*. Denver, Colo: Northern Great Plains Resources Program, 1974, p. 3.

[2] U.S., Department of the Interior, Geological Survey. *Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming*, Open File Report 75-631. Denver, Colo.: Geological Survey, 1975, p. 5.

TABLE 13-25: PROJECTED WATER DEMAND FOR ENERGY DEVELOPMENT IN UPPER MISSOURI RIVER BASIN[a]

Energy Type	Water Requirements (acre-feet per year)								
	Low Demand			Nominal Demand			Low Nuclear Availability		
	1985	1990	2000	1985	1990	2000	1985	1990	2000
Coal Mine	4,722	12,276	29,380	5,580	15,742	39,556	7,068	22,196	53,206
Slurry Pipeline	18,390	91,950	229,070	18,390	110,340	312,630	18,390	183,900	496,530
Gasification	0	18,172	245,322	0	27,258	408,870	0	18,172	353,440
Liquefaction	0	0	34,920	0	0	26,190	0	0	17,460
Power Plant	117,600	294,000	411,600	147,000	382,200	529,200	176,400	499,800	882,000
Oil Shale	0	0	0	0	0	0	0	0	0
Uranium	7,555	18,132	33,242	9,066	24,176	46,841	3,022	1,511	0
Total	148,257	434,530	941,542	180,036	559,716	1,363,287	204,880	725,579	1,802,636

[a] Taken from Section 13.1, SRI Model regional demand predictions and from the Energy Resource Development System Descriptions assuming that the following facility water requirements hold:

Facility	Assumed Size	Load Factor	Water Requirements (acre-feet per year)
Coal Mine	5 million tons per year	100%	126
Slurry Pipeline	25 million tons per year	100%	18,390
Coal Gasification	250 million cubic feet per day	90%	9,086
Coal Liquefaction	100,000 barrels per day	90%	17,460
Power Plant	1,000 megawatts-electric	70%	29,400
Oil Shale Retort	100,000 barrels per day	90%	16,650
Uranium Mill	1,000 tons per year	100%	1,511

TABLE 12-26: WATER REQUIREMENTS FOR POPULATION INCREASES IN THE UPPER MISSOURI RIVER BASIN[a,b]
(acre-feet per year)

	Low Demand					Nominal Demand			Low Nuclear Availability			
	1980	1985	1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
Montana North Dakota Wyoming	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Above water consumed in 1975.

[b] Assuming 150 gallons per capita per day using population increase estimates from Section 11.4.

by 15-18 percent or 250,000-272,000 acre-ft/yr[1], depending on the level of development. Using wet-dry or all dry cooling could reduce these requirements even further but at a slightly higher economic cost.[2]

Water requirements resulting from the increases in population associated with the three levels of development have been projected and are shown in Table 12-26. Assuming a daily consumption of 150 gallons per person, these water requirements are less than 80,000 acre-ft/yr which is about 6 percent of that required for energy facilities. Even if the per-capita water consumption estimate is doubled, the requirements for population increases would still be less than 10 percent of that needed for facilities.

Total water requirements for the UMRB in the year 2000 for the three levels of development assumed in Section 12.1 are: Low Demand case, 1.05 million acre-ft/yr; Nominal Demand Case, 1.43 acre-ft/yr; and Low Nuclear Availability case, 1.09 million acre-ft/yr.

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[1] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2] The water consumption and economic consequences of using wet-dry cooling will be evaluated during the remainder of this study.

C. Water-Related Impacts of Energy Development in the UMRB

1. Surface Water

The water requirements for energy development identified above are 8-15 percent of the water available for use in the UMRB. Because of the limited data on water availability and energy requirements for individual rivers in the UMRB, estimates cannot be made of the impacts that energy development might have on particular rivers, although demands on the Yellowstone from Powder River coal development will probably be substantial. However, the overall impact on the basin from energy developments are not expected to be serious.

If water depletions in the UMRB are significant, there may be an effect on the length of the navigation season in the Lower Missouri. If 10 million acre-ft/yr are withdrawn from the UMRB, this season would drop from a nominal 8 months to zero for 11 of the next 75 years.[1] If only 600,000 acre-ft/yr are withdrawn, the season would drop to zero for only 1 of the next 75 years.[2]

Much of the Fort Union Coal Region is in areas not served by nearby streams; thus, a regional water system may be required to service a large part of the proposed development.[3] If a regional system is developed, there will be an effect on the river as well as on the land area disturbed by the construction. The magnitude of the effect will be related to several design considerations, including the location of the intakes, types of intakes, and amount of water withdrawn. Several smaller diversions at a variety of locations would probably reduce the local effect on the stream but would increase the amount of land disturbed.

Water quality impacts due to energy development in the UMRB have been estimated for levels of development similar to those assumed here and found to be small. TDS increases in the Missouri

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[1] U.S., Army, Corps of Engineers, Missouri River Division, Reservoir Control Center. Missouri River Main Stem Reservoirs Long Range Regulation Studies, Series 1-74. Omaha, Nebr.: Corps of Engineers, 1974, p. 23.

[2] U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. V-21.

[3] U.S., Department of the Interior, Bureau of Reclamation. Appraisal Report on Montana-Wyoming Aqueduct. Billings, Mont.: Bureau of Reclamation, 1974.

River at Bismarck were estimated to be from 13 mg/ℓ to 454 mg/ℓ.[1] TDS changes in tributaries were not consistent, with increases predicted in some and decreases in others. Both the amount of change and direction depend on assumptions concerning level and type of development and the amount and quality of return flows to the streams.

Although the most significant water-related impacts in the UMRB will be due to water depletions and changes in water quality, a number of additional impacts may also be important. These include municipal and industrial water supply and wastewater treatment problems, in-stream water needs to support fish and wildlife, and disposal of effluents from energy facilities. Most of these impacts are discussed in the site-specific chapters or in Section 12.3.1, and these sections should be consulted for details. Problems and issues resulting from these impacts are discussed in Section 14.2.

3. Groundwater

Groundwater withdrawals should be increased by the projected energy resource development scenario. Some withdrawals will be for mine dewatering operations, but most withdrawals will be for consumption. Yield from shallow aquifers is not sufficient to meet the water needs of the energy conversion facilities.[2] However, groundwater will probably make significant contributions to water supply for the associated population growth. If the combined withdrawals from the Fort Union aquifers exceed the rate of recharge, then wells, springs, and seeps may go dry, and lower base flows in streams and rivers could occur.

The Madison aquifer will probably be used if groundwater is needed for the scenario energy facilities. The Madison may be able to supply a significant fraction of the water required by the facilities, but groundwater mining may occur as a result.[1] This has occurred in the vicinity of Midwest, Wyoming, where about 12-14 wells were drilled for waterflood supplies for oil field secondary recovery. This development caused a decline of 3,000 feet in the water levels in wells, with an area of influence extending under six townships.[2]

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[1] Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974, p. 66.

[2] Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. Water Resources Problems Related to Mining. American Water Resources Association Proceedings, Vol. 18 (1974), p. 212.

Mining may affect local groundwater systems by interrupting or changing aquifer flow and by introducing effluents into groundwater aquifers. The surface acreage likely to be disturbed by mining in the UMRB is shown in Table 12-27. Over 2,100 square

TABLE 12-27: SURFACE ACREAGE ULTIMATELY DISTURBED BY MINING IN THE UPPER MISSOURI RIVER BASIN[a]
(acres)

Location	Low Demand	Nominal Demand	Low Nuclear Availability
Northern Great Plains[b] (North Dakota Lignite)	446,700	480,000	540,000
Powder River[c]	395,700	581,600	813,400

[a] Based on the number of mines hypothesized in the SRI model (see Section 12.1), a coal density of 85 pounds per cubic foot, and seam thicknesses given below.

[b] Includes Billings, Bowman, Dunn, Hettinger, McKenzie, McLean, Mercer, Oliver, Slope, Stark, and Williams counties. Assumed average seam thickness of 12.5 feet.

[c] Includes: Powder River, Big Horn, and Rosebud, Montana counties (assumed average seam thickness 27 feet); and Campbell, Johnson, and Sheridan Counties, Wyoming (assumed average seam thickness 64 feet).

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[1] Swenson, Frank A. *Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming.* Denver, Colo.: Northern Great Plains Resources Program, 1974; U.S. Department of the Interior, Geological Survey. *Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming.* Open-File Report 75-631. Denver, Colo.: Geological Survey, 1975.

[2] Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. *Water Resources Problems Related to Mining.* *American Water Resources Association Proceedings*, Vol. 18 (1974), p. 217.

miles may be affected, and in some counties, as much as 18 percent of the land area may be surface-mined (see Section 12.4).

Mining and energy conversion facility effects on groundwater systems in the UMRB will be similar to those described earlier for the UCRB. However, a number of possible impacts cannot be adequately assessed because of a lack of detailed knowledge about UMRB groundwater. Data on both the rate of movement of groundwater and the fate and effects of pollutants in groundwater systems are needed.[1]

12.3.3 Summary of Regional Water Impacts

A. Upper Colorado River Basin

In the UCRB, water demands for energy uses for the year 2000 will be 38-71 percent of presently unallocated water for the three levels of energy development being considered. If water conservation efforts are made at each of the energy facilities, this demand can be reduced by 18-22 percent or 162,000-185,000 acre-ft/yr.

Meeting these water requirements will increase the salinity of the Colorado even if no pollutants are discharged from the facilities. This will occur because salt from natural sources will not decrease and energy facility consumption will decrease in-stream dilution flows, thereby increasing salt concentrations.

The competition for water in the UCRB will become more intense as a consequence of energy development. Municipalities, Indians, and in-stream flow requirements will all have increased demands over the next 24 years. The available supply is not likely to be adequate for all potential users, and changes in stream flow will affect aquatic biota.

Groundwater and surface water must be considered parts of a single resource system if water management is to be well-informed. Groundwater resources will be used primarily for municipalities, and both municipal withdrawals and possible groundwater pollution from sewage disposal will affect the resource. An additional groundwater impact may occur as a result of mine dewatering. The most serious impact from this activity will be on ecology since the springs and seeps may dry up as a result of mine dewatering.

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[1] Northern Great Plains Resources Program, Water Work Group, Ground Water Subgroup. *Shallow Ground Water in Selected Areas in the Fort Union Coal Region*, Open-File Report 74-48. Helena, Mont.: U.S., Department of the Interior, Geological Survey, 1974, p. 13.

Adequate impact assessment requires more data on present allocations and uses of water in the UCRB and on groundwater resources. Efforts to acquire this information are currently under way.

B. Upper Missouri River Basin

Impacts on the UMRB due to energy development will not be as serious as those in the UCRB, primarily because considerably more water is available in the Missouri. Based on regionwide figures, energy facilities will require 8-15 percent of the water available in the year 2000. However, problems may arise in getting the water to energy facilities. Pipelines will probably be necessary in many of the developments in the Powder River Resource Region.

The navigation season on the Lower Missouri will be reduced as a result of depletions for energy facilities in the Upper Basin. Depletions of 600,000 acre-ft/yr would result in 1 of the next 75 years having no navigation season; depletions of 10 million acre-ft/yr would result in 11 of the next 75 years with no navigation season.

Groundwater from the Madison aquifer may be used to supplement surface water for energy facilities in the UMRB. Because of low porosity in the aquifer, municipal users of this groundwater source may be affected. Drilling deeper wells or finding supplemental municipal sources may be necessary. However, these assessments are preliminary because of insufficient information about groundwater.

12.4 SOCIAL, ECONOMIC, AND POLITICAL IMPACTS

12.4.1 Introduction

In this section, social, economic, and political impacts of western energy development are analyzed and discussed for the western region and, more selectively, for the nation as a whole. Population impacts are considered first, primarily in terms of net population changes expected in the West as a result of each of the three levels of energy resource development being examined. Following is an economic and fiscal analysis which estimates changes in personal income, public services, and economic structure in the western region. Land use, social and cultural effects, and political and governmental impacts are discussed next, followed by an analysis of impacts on the availability of personnel, materials and equipment, and capital. The last section summarizes the most significant regional and national impacts of western energy resource development.

12.4.2 Population Impacts

This section analyses the large-scale, regionwide population changes in contrast to the site-specific analyses reported in Chapters 6-11. For each of the three cases of the SRI model described in Section 12.1,[1] manpower requirements for construction and operation were obtained from Bechtel's *Energy Supply Planning Model*.[2] Average (rather than peak) construction employment was used for each of the energy facilities that are projected to be built in given time periods.

A. Regionwide

One of the most important variables that will influence population change is the location of the necessary personnel. This can be considered as two questions: how many of the required workers will be available locally, and where will the others come from? A greater number of local workers will decrease the need for in-migration from elsewhere. Limited current information indicates that about 46 percent of the workforce is recruited locally in the Four Corners states (Arizona, Colorado, New Mexico, and Utah), and about 34 percent in the Northern Great Plains states (Montana, North Dakota, South Dakota, and Wyoming).[3] Over 30 percent of construction workers in the Northern Great Plains came from outside the western region, while only 10 percent came from outside the West to the Four Corners construction sites (primarily because of the larger population in the area).[4] In the future, more workers are likely to move from outside the West, and somewhat fewer will probably be available in local areas. However, in the absence of other data, the available estimates of 66 percent net in-migration to local areas in the Northern Great Plains and 54 percent net in-migration to local areas in the Four Corners states are used here.[1]

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[1] Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] Carasso, M., *et al.* *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

[3] Mountain West Research. *Construction Worker Profile*, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 14-17.

[4] *Ibid.* The limited number of energy projects considered by this study (19) makes it difficult to expect future energy developments to be identical to those in the survey.

In migrant employment in an area was assumed to induce secondary employment and additional population according to the multipliers shown in Table 12-28; these were used in an economic base methodology described in the Introduction to Part II.[2]

TABLE 12-28: SECONDARY/BASIC EMPLOYMENT MULTIPLIERS AND POPULATION/ EMPLOYEE MULTIPLIER FOR OPERATION EMPLOYMENT

Year	Secondary/Basic Employment[a]	Population/Employee
1980	0.4	3
1985	0.8	3
1990	0.8	3
2000	1	3

[a] These economic multipliers are expected to increase over time as the regional economy becomes more diverse and internally self-stimulating. See Crawford, A.B., H.H. Fullerton, and W.C. Lewis. *Socio-Economic Impact Study at Oil Shale Development in the Uintah Basin, for White River Shale Project.* Providence, Utah: Western Environmental Associates, 1975, pp. 147-158.

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[1] Mountain West Research. *Construction Worker Profile, Final Report.* Washington, D.C.: Old West Regional Commission, 1976, pp. 14-17. This assumption appears to balance future in-migration to the region with movements within and among the western states.

[2] The economic base methodology was chosen over the alternative, input-output analysis. For a discussion of the two methods, see Stenehjem, Erik J. *Forecasting the Local Economic Impacts of Energy Resource Development: A Methodological Approach,* ANL/AA-3. Argonne, Ill.: Argonne National Laboratory, 1975.

The population effects of facility construction and operation in the regional scenario vary among the three Stanford Research Institute's (SRI) levels of development.[1]

Construction employment is based on continuous building activity in the region to meet development projections. This average construction level will result in the population increases shown in Table 12-29. Overall increases (construction plus operation-related) show that construction activity would have the greatest impact before 1980 and the least in the 1990's (Table 12-30). With the exception of the Nominal case in the 1990-2000 period, which includes large-scale oil shale development, construction activity would add less than 25 percent to the operation-related population increase after 1980.

Operation-related or permanent population increases of the Nominal case projection would result in 241,400 new people coming to the region by 1990 and a 861,100 increase by 2000. The large increase during the 1990's would primarily be due to the assumptions in SRI's model that result in large-scale oil shale development in Colorado and extensive coal production in the Northern Great Plains. Although the increases would not be large on a regionwide basis (less than a 10-percent increase in the highest projection), the parts of the region receiving the greatest proportion of the energy-related population are those with small populations currently, not the metropolitan areas which make up about half of the region's present population.

B. Subregional

Disaggregation of the energy supply areas considered in the SRI model provides an analysis of subregional impacts to state and substate areas. Considerable error is potentially built into this procedure, even on the state level, because South Dakota and Arizona are omitted from the energy supply region. County-level projections appear to include many reasonable locations within states but concentrate resource development in too few areas.[2] Further, the SRI-Ford Foundation assumptions result in high levels of oil shale production, most of which was allocated to Colorado in the disaggregation.[3] As a result, the western Colorado area is projected to receive 16-20

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[1] See Section 12.1 for a description of the three levels of development.

[2] For example, Sweetwater County and Carbon County, Wyoming do not include any coal development.

[3] As noted earlier, some refinement of the Stanford Research Institute's levels of development will be part of Phase II of this technology assessment.

TABLE 12-29: CONSTRUCTION-RELATED POPULATION INCREASES AFTER 1975 IN EIGHT-STATE REGION[a]

Level of Development	1980	1985	1990	2000
Nominal Case				
Construction-Related Population	38,900	38,900	39,500	386,500
Percent of Permanent Increase	68.7	21.7	16.4	44.9
Low Demand Case				
Construction-Related Population	15,900	16,262	14,100	132,400
Percent of Permanent Increase	35.3	12.3	7.9	26.8
Low Nuclear Availability Case				
Construction-Related Population	21,300	27,900	18,000	201,000
Percent of Permanent Increase	32.5	13.4	6.6	21.6

[a] Based on average employment and number of new facilities in each period; a single multiplier of 2.0 is used, resulting in a possible underestimate of about 30-50 percent in addition to error ranges on Bechtel's work force estimates (see Section 3.4).

TABLE 12-33: OVERALL (CONSTRUCTION PLUS OPERATION) EXPECTED POPULATION INCREASES AFTER 1975 DUE TO ENERGY DEVELOPMENT IN EIGHT-STATE REGION[a]

Year	Nominal Case	Low Demand Case	Low Nuclear Availability Case
1980	95,500	60,900	86,800
1985	218,300	147,900	235,900
1990	280,900	192,900	289,200
2000	1,247,600	768,300	1,133,100

[a] The 1975 estimated population for the eight states was 9,551,000. See U.S., Department of Commerce, Bureau of the Census. "Estimates of the Population of States, By Age: July 1, 1974 and 1975 Advanced Report." Current Population Reports, Series P-25, No. 619 (January 1976).

percent of the total regional population increase in each scenario by 2000 (Table 12-31). The sub-state areas whose population increases vary most among the three levels of development are those where uranium mining and milling facilities are projected to be located.[1]

Aggregating the data by state and separating construction and operation based population illustrates the distribution of impacts among the western states (Table 12-32). Overall, the Low Demand case would result in a population increase 26 percent below that of the Nominal case. The greatest decrease would be in Utah (43 percent lower), whereas Colorado would be least affected (17 percent lower). The Low Nuclear Availability case would result in an average increase 8 percent above that of the Nominal case, but the distribution differs considerably because of the emphasis on coal and the elimination of uranium production. These assumptions result in a decrease in the population projections for New Mexico and Southern Colorado, when compared to the Nominal case, and an increase in Montana's population.

A comparison of the energy-related population growth projected here with a set of projections for the same period based on

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[1] For example, McKinley and Valencia Counties in New Mexico and Carbon County in Wyoming. Counties were allocated for uranium production according to data mapped in U.S., Energy Research and Development Administration. Statistical Data of the Uranium Industry, January 1, 1976. Grand Junction, Colo.: Energy Research and Development Administration, 1976, p. 24.

TABLE 12-31: PERMANENT POPULATION ADDITIONS AFTER 1975 FOR ENERGY AREAS OF SIX WESTERN STATES, FOR THREE SCENARIOS[a]

Year	Nominal Case	Low Demand Case	Low Nuclear Availability Case
COLORADO Garfield, Mesa, and Rio Blanco Counties Area			
1980	1,800	0	0
1985	17,800	11,200	29,400
1990	34,600	28,600	30,700
2000	240,800	198,900	331,600
Huerfano County Area			
1980	0	3,600	5,400
1985	11,600	11,600	14,400
1990	11,600	11,600	13,800
2000	12,700	12,700	25,700
UTAH Kane and Garfield Counties Area			
1980	6,400	2,200	4,600
1985	10,800	2,900	11,900
1990	12,200	2,900	15,500
2000	12,800	4,100	26,600
Uintah and Grand Counties Area			
1980	0	0	0
1985	600	0	0
1990	500	0	0
2000	27,000	18,600	24,500
NEW MEXICO Northwestern Area (San Juan, McKinley, and Valencia Counties)			
1980	6,300	3,700	2,300
1985	14,600	11,400	5,800
1990	20,600	15,200	7,300
2000	54,200	39,700	24,200

TABLE 12-31: (Continued)

Year	Nominal Case	Low Demand Case	Low Nuclear Availability Case
NEW MEXICO Southeastern Area (Lea, Eddy, Roosevelt, and Chaves Counties)			
1980	9,900	8,200	9,900
1985	12,900	10,500	15,100
1990	6,900	4,800	6,900
2000	0	0	0
MONTANA Big Horn, Powder River, and Rosebud Counties Area			
1980	11,600	10,400	20,000
1985	53,400	38,100	75,600
1990	74,800	48,900	98,000
2000	215,100	149,400	290,000
WYOMING Campbell County Area			
1980	14,200	8,800	16,200
1985	25,000	19,800	26,600
1990	32,200	26,300	55,800
2000	81,100	52,300	91,400
Johnson, Sheridan, Converse, Natrona, Carbon, Fremont, and Sweetwater Counties			
1980	2,400	900	7,000
1985	10,000	7,200	16,800
1990	12,800	10,200	25,800
2000	68,900	50,300	76,800
NORTH DAKOTA Dunn, Mercer, Oliver, and McLean Counties Area			
1980	7,000	7,000	7,000
1985	14,000	14,500	16,600
1990	21,400	25,600	25,800
2000	84,600	52,400	76,800

TABLE 12-31: (Continued)

Year	Nominal Case	Low Demand Case	Low Nuclear Availability Case
NORTH DAKOTA (Continued) Billings, Bowman, Hettinger, McKenzie, Slope, Stark, and Williams Counties			
1980	0	0	0
1985	4,500	4,600	13,800
1990	13,800	4,600	17,300
2000	61,700	61,500	80,200

[a]Based on disaggregation of results in Cazalet, E. et al. A Western Energy Development Study: Economics. Menlo Park: Stanford Research Insitute, 1976. Manpower estimates are from M. Carasso, et al., The Energy Supply Planning Model. San Francisco: Bechtel Corporation, 1975. Multipliers used for population estimates are in Table 12-30. These estimates are probably as much as 40 percent high or 20 percent low for the given counties even assuming the regional supply levels involved in each case of the SRI projections.

TABLE 12-32: POPULATION INCREASES IN WESTERN STATES AFTER 1975 DUE TO ENERGY DEVELOPMENT

State	Year	Nominal		Low Demand		Low Nuclear	
		Construction	Operation	Construction	Operation	Construction	Operation
Colorado	1980 1985 1990 2000	200 13,100 11,100 122,200	1,800 29,500 46,200 251,600	400 8,300 11,160 99,900	3,400 22,800 40,300 221,400	600 12,960 7,400 125,000	5,400 31,400 46,300 257,400
New Mexico	1980 1985 1990 2000	15,600 1,300 1,200 13,800	16,200 27,600 27,500 54,300	12,720 3,460 440 3,440	12,100 21,900 20,100 35,700	14,620 4,590 400 13,440	12,300 20,500 14,300 24,300
Utah	1980 1985 1990 2000	3,100 400 2,500 15,000	6,400 11,400 12,700 39,800	2,700 0 0 11,160	2,200 2,900 2,960 22,700	2,900 2,900 7,700 17,900	4,600 11,900 15,900 51,300
Montana	1980 1985 1990 2000	7,400 12,200 10,400 83,800	11,600 53,400 74,800 215,100	4,900 9,400 2,200 57,530	14,400 38,100 48,900 149,400	9,400 26,700 10,570 93,000	20,000 75,600 98,000 290,000
North Dakota	1980 1985 1990 2000	6,200 9,300 12,400 100,700	7,000 22,500 35,200 148,300	6,200 6,400 9,960 61,370	7,000 19,000 30,100 113,900	6,200 15,100 8,770 102,200	7,970 29,600 43,100 157,000
Wyoming	1980 1985 1990 2000	6,400 4,600 1,500 54,300	16,400 35,000 45,000 150,000	4,460 4,900 4,020 31,250	9,700 27,000 36,500 122,600	8,600 3,200 6,100 48,900	16,200 36,600 55,800 152,400

long-term trends made by the Department of Commerce's Office of Business Economics (now the Bureau of Economic Analysis) and the Department of Agriculture's Economic Research Service (OBERS projections) gives an indication of the relative magnitude of energy-related impacts (Table 12-33).[1] The OBERS Projections merely extend past trends into the future, with the result that: the out-migration in the Northern Great Plains is expected to continue; such rapidly growing metropolitan areas as Denver, Phoenix, Salt Lake City, and Albuquerque are projected to continue growing; and mining activity in the West is expected to continue its trend through only about 1970. This involves very slow growth when compared with present activity. Because of recent events, which have broken some seemingly long-term trends, the actual population and economic activity levels in the West through 1975 show the OBERS projections to be large underestimates.[2] Since energy development in the major impetus for reversal of the trends in the Northern Great Plains states, and is a considerable stimulus in the Four Corners states, the OBERS projections can be assumed to be the likely state of the western region in the absence of energy development. Thus, the greatest impact from energy development will be in those states which were expected to continue to lose population (generally the Northern Great Plains), whereas the smallest impact will be in those states where other growth was projected (the Four Corners states).

To summarize, the population impacts from western energy developments will not be large regionwide (at most a 13-percent increase through 2000). However, these developments will largely take place far from the metropolitan areas and will impact small towns and rural areas most. In some areas, a 10-fold population increase by 2000 is possible under conditions similar to the Nominal case development considered here. Examples of effects in these areas are included in the site-specific analyses of Chapters 6-11.

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[1] U.S., Department of Commerce, Bureau of Economic Analysis and Department of Agriculture, Economic Research Service, 1972 OBERS Projections: Economic Activity in the U.S., Vol. 4: States, for the U.S. Water Resources Council. Washington, D.C.: Government Printing Office, 1974.

[2] U.S., Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis Division. "Tracking the BEA State Economic Projections." Survey of Current Business, Vol. 56 (April 1976), pp. 22-29. For example, Montana, North Dakota, South Dakota, and Wyoming have grown in population in contrast to projected steady declines. New Mexico is nearing its projected population for the year 2000; all other states in the region also are well above the estimates.

TABLE 12-33: COMPARISON OF POPULATION INCREASES FOR NOMINAL CASE ENERGY DEVELOPMENT WITH OBERS POPULATION PROJECTIONS, 1980-2000

State	Year	Energy-Related Population Increase[a]	OBERS Projection[b]	Energy-Related Increase As A Percentage of OBERS Projection	Actual 1975 Population
Colorado	1980	2,000	[illegible]	0.1	2,534,000
	1990	[illegible]	[illegible]	[illegible]	
	2000	375,000	3,134,100	12	
New Mexico	1980	21,800	[illegible]	2	1,147,000
	1990	26,700	[illegible]	[illegible]	
	2000	68,100	[illegible]	5.8	
Utah	1980	2,900	1,180,100	0.2	1,206,000
	1990	[illegible]	[illegible]	[illegible]	
	2000	64,000	1,618,100	3.9	
Montana	1980	19,000	800,700	2.3	748,000
	1990	[illegible]	[illegible]	[illegible]	
	2000	295,000	856,400	35.1	
North Dakota	1980	12,000	578,705	2.1	635,000
	1990	47,000	563,400	8.3	
	2000	249,000	545,200	45.7	
Wyoming	1980	23,000	330,200	7	374,000
	1990	42,700	[illegible]	14	
	2000	206,300	336,400	61.3	
Arizona[c]	1980		[illegible]		2,224,000
	1990		[illegible]		
	2000		3,085,000		
South Dakota[c]	1980		654,000		683,000
	1990		647,500		
	2000		637,000		

[a] Operation plus construction phases; from Table 12-32.

[b] Source: U.S., Department of Commerce, Bureau of Economic Analysis and Department of Agriculture, Economic Research Service. 1972 OBERS Projections: Economic Activity in the U.S., Vol. 4: States, for the U.S. Water Resources Council. Washington, D.C.: Government Printing Office, 1974.

[c] Arizona and South Dakota were not expected to be significantly impacted directly by the levels of energy development analyzed. See Section 12.1

12.4.3 Economic Impacts

A. Personal Income

New income will be generated in the region because of job opportunities for both newcomers and current residents. Based on the population increases shown in Table 12-33 and income data for workers in communities with energy development,[1] changes to states' aggregate personal incomes and per-capita income for the Nominal case energy development can be determined (Table 12-34).

According to these projections, energy development is expected to increase total income in the six-state area by about 30 percent[2] over the 26-year period, an absolute increase from $35.8 to $46.5 billion per year. Further, most of the increase would occur during the 1990's, corresponding to the most intensive energy development; thus, energy development alone would induce an annual growth rate of income of 2.04 percent during that decade.

On the state level, Wyoming would experience the greatest relative gain in aggregate personal income (+78.7 percent over the quarter-century), and Utah would experience the least (+8.2 percent). By the per-capita measure, Wyoming would make the greatest absolute gain ($910 per year), and Utah would have the least ($170 per year).[3] The only change in rank order on the basis of per-capita incomes will occur in the 1990's when Wyoming is expected to surpass Colorado.

These increases in per-capita income would be due mostly to construction; thus, incomes would probably slip to about current levels when energy-related construction diminishes because

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[1] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50.

[2] An annual growth rate of 1.0 percent compound. This is in addition to income growth from other sources, such as productivity gains and national trends.

[3] Although not calculated here, South Dakota and Arizona will experience the least new energy development of the eight states studied and the smallest income gains from new energy developments.

TABLE 12-34: CHANGES IN ANNUAL PERSONAL INCOME, SIX WESTERN STATES, NOMINAL CASE ENERGY DEVELOPMENT[a]

Additions to Aggregate Income Above 1975 Levels (millions of 1975 dollars)				
State	1980	1985	1990	2000
Colorado	16	383	478	3,414
New Mexico	318	217	215	572
Utah	86	88	124	482
Montana	164	497	618	2,374
North Dakota	119	258	379	2,165
Wyoming	185	286	321	1,632
Six State Total	888	1,729	2,135	10,639

Statewide Per Capita Incomes[b] (constant 1975 dollars)					
State	1974	1980	1985	1990	2000
Colorado	5,970	5,970	6,020	6,020	6,380
New Mexico	4,620	4,770	4,690	4,690	4,830
Utah	4,970	5,010	5,000	5,010	5,140
Montana	5,330	5,410	5,520	5,540	5,190
North Dakota	6,200	6,260	6,290	6,330	6,900
Wyoming	5,760	5,890	5,920	5,890	6,570
Six State Average	5,475	5,550	5,575	5,580	5,986

[a] With the population projections as a base, our estimated error range for the income changes is an additional ±20 percent. National trends or competition for labor within the region could cause these to be even greater underestimates.

[b] These are per-capita incomes; family or household incomes would be at least three times these figures.

construction labor generally is paid more than operational labor.[1] Gains to many residents of the West will not be very large unless they become employed in energy-related jobs.

B. Current Economic Structure

The economic structures of the eight states vary considerably, with agriculture dominating in the Northern Great Plains and tourist-related service activities dominating in the Four Corners states (Table 12-35). Manufacturing activities are less important in the region than nationally, and federal government employment is greater. Although only a small proportion of income compared to other sectors, mining and other energy development income is particularly important in Wyoming, New Mexico, Arizona, and Utah.

The energy resource areas within the region are also the areas with the greatest current agricultural activities.[2] This suggests that the land-use, water-use, and employment impacts of energy resource development will fall disproportionately on agriculture. Since employment in agriculture has been declining, energy development may hold and/or bring back young people who have been moving out, in addition to bringing new in-migration. The trend has been for total agricultural income to increase, although employment or farms declines, so that the relative economic importance of agriculture is better indicated by total farm income, as shown in Table 12-35.

C. Sectoral Shifts

As suggested above, the largest single economic change in most areas is expected to be the growth of energy sectors, with agriculture sharing a decreasing proportion of overall economic activity. If significant amounts of water or land are removed from agricultural use, absolute decreases in agricultural

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[1] In fact, in three states (North Dakota, Wyoming, and Colorado) current per-capita incomes are higher than the average assumed for new operation workers and their families ($5,660). This is because of current construction and other high-wage occupations. Agricultural income in 1969, the year of census data collection, caused some of the problems with income comparisons.

[2] Detailed breakdowns of income by industry and local area can be found in U.S., Department of Commerce, Bureau of Economic Analysis, "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 12-35: PERCENTAGE OF INCOME DERIVED FROM ECONOMIC SECTORS IN THE WESTERN REGION, 1972

Sector	U.S. Average	U.S. Non-metropolitan Average	Colorado	New Mexico	Utah	Arizona	Montana	North Dakota	Wyoming	South Dakota
Farm	3.3	11.4	4.2	5.5	2.7	3.5	18.7	28.6	11.6	29.6
Federal Government Civilian	4.5	3.5	6.3	10.2	11.9	5	5.8	4.7	5.7	5.4
Federal Military	2.5	3.1	5.2	5.5	1.9	4.5	2.9	6.1	3.0	3.5
State and Local Government	11	12.4	11	15.7	13	12.3	11.9	11	14.4	12.1
Manufacturing	26.9	26	15.9	6.6	15.9	15.1	9.9	4.5	6.5	7.7
Mining	[illegible]	2.6	1.8	5.4	3.9	4.2	2.9	0.8	11.1	3.2
Contract Construction	6.3	5.7	8.7	7.7	7.2	6.6	6.8	7.3	9.6	10.7
Transportation, Communication, and Utilities	7.3	5.7	7.7	7.6	8.2	6.1	8.9	6.6	10.4	5.8
Wholesale and Retail	16.4	16.1	17.9	15.2	17.2	[illegible]	15.4	20.7	13.7	15.5
Finance, Insurance, and Real Estate	5.6	2.8	5.9	4.4	4.6	[illegible]	3.7	2.6	3.3	3.5
Services	15.1	12.2	16.9	18.3	13.2	[illegible]	12.7	9.9	10.5	10.6
Other	0.3	0.6	0.3	0.3	0.2	0.6	0.3	0.6	0.2	0.6

Source: U.S. Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75; and U.S. Department of Commerce, Bureau of Economic Analysis. "Personal Income by Major Sources, 1970-73." Survey of Current Business, Vol. 55 (August 1974), pp. 39-41.

activity are possible in some areas.[1] However, other aspects of the economy also would be altered from the expanded population, income, and retail activity. For example, several cities in the region can be expected to experience increased economic activity because they are currently service centers in the vicinity of energy development. Gillette, Wyoming, Farmington, New Mexico, and Dickinson, North Dakota are likely to experience energy-induced growth. Larger regional centers would benefit from both wholesale and retail activity as well as more specialized services. Although not at the center of extensive energy resource areas, such cities as Bismarck, North Dakota, Billings, Montana, Casper, Wyoming, and Grand Junction, Colorado would also experience increases in economic activity. Finally, regional manufacturing centers such as Denver, Pueblo, and Salt Lake City are likely to be positively affected by western energy development, particularly for manufactured goods which would be more expensive if purchased from outside the West. Although some new centers may develop,[2] most economic benefits from the purchase of energy development-related materials and equipment are expected to accrue to the diversified manufacturing centers of other areas of the nation, such as the industrial northeast. (More detail on regional shifts may be found in the Materials Availability discussion, Section 12.4.8.)

Some manufacturing industries could develop around energy conversion facilities, particularly the synthetic fuel plants which produce various useful by-products. In part, this will depend on such factors as economies of scale. For example, one 250 million cubic feet per day gasification plant will yield some 81,000 tons per year of naphtha. Processing this volume may not be economical, but if several other gasification facilities are also located nearby, "the volume of by-products produced by more than one plant may result in the construction of plants near the gasification complexes for processing them".[3] Other factors, however, such as transportation costs and pollution regulations, may tend to prevent these large-scale industrial operations.

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[1] See, for example, Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: University of Montana, Joint Water Resources Research Center, 1974, pp. 189-193.

[2] For example, Bucyrus-Erie Co., a mining equipment concern, has decided to build a plant in Pocatello, Idaho.

[3] Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. III-2.

D. Local Inflation

Price levels have always been higher in sparsely settled areas, primarily for two reasons: transportation costs from places of manufacture and lack of competition in small towns. The only items with consistently lower prices are those produced locally, such as meat in most western locations.

When isolated towns "boom", the demand for goods and services increases, and prices rise and/or shortages occur. In recent western boom towns, residents have expressed dissatisfaction with the availability of certain items more often than others, especially housing, land, and professional and retail services.[1] Employers have also experienced a general shortage of labor. However, the retailing sector tends to respond most quickly and, in fact, local consumers eventually have access to a greater variety of goods when larger, more specialized stores are built.

Boomtown inflation affects different people in various ways. Inflation will benefit sellers and increase costs for buyers. For example, landowners will benefit if they sell, but renters will suffer from higher rents. Depending on methods of property taxation, landowners must pay taxes with higher assessed valuations on their holdings. In the local labor market, employers will suffer from increased wages while workers will benefit. Increased wages will usually more than compensate for increased prices, but some people, especially retirees, may not be in a position to take advantage of the expanded labor market.

Local government also functions as a participant in the local economy. As a buyer, it purchases mainly labor and must compete with the energy developers. Since most taxes are based on property assessments, revenues will eventually rise with the general pace of inflation. However, assessments are often out of date; thus, revenues may lag behind local governmental expenditures.[2] Increases in tax rates should not be necessary. In fact, rates can be expected to decline in some areas after tax revenues begin to outpace needs. Moreover, state law may specify that land be assessed according to its value for its present use. Thus, a rancher could experience substantial gains in the value of his land due to its potential for urban development without the land being reassessed for tax purposes.

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[1] Mountain West Research, Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[2] Fiscal impacts on local government are considered in more detail in the social, economic, and political section of Chapters 6-11.

12.4.4 Public Services

A. Expenditures

Much of the development of energy resources in the West will occur in sparsely populated areas. Small communities will face greatly expanded demands for services. Some communities of less than 5,000 people will increase their populations many times over. Thus, large investments in public facilities will be required, and operating expenses will be much higher than before the boom. Public investments at the local level will be devoted largely to water supply, sewage treatment, and school buildings (Table 12-36).[1] Altogether the Nominal Case level of development would necessitate local capital expenditures of about $2.4 billion by the end of the century, most of this between 1990 and 2000 when the annual rate of new investment is expected to reach $184 million (over 10 times the 1975-1980 requirement). This pattern is expected to hold for all the states in the study area except New Mexico where construction activity is expected to peak between 1975-1980.[2]

As noted above, local governments will also have to increase their operating budgets. About 80 percent of the expenditures shown in Table 12-37 will go for education. In other respects, such as time phasing, operating expenditures follow the same patterns as capital expenditures.

State governments will also face increased demands for services but at a lower growth rate. Given the levels of energy development analyzed here, the most rapid state-level population growth can be expected in Wyoming: 3.22 percent compounded over the 1990-2000 period. Since this rate will make it easier to finance capital expenditures out of current revenues, capital and operating costs are tabulated together here. Assuming that state per-capita expenditures remain at present levels,[3] newcomers will induce new spending as reported in Table 12-38.

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[1] A consistent per capita figure is used in the evaluations here to facilitate comparisons between states.

[2] After 1980, much of the gas and oil production in the southeastern portion of New Mexico is expected to close down, according to this disaggregation of the Stanford Research Institute model. See Section 12.1.

[3] As reported in U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975. A constant per-capita expenditure assumption is plausible because as population rises, more services are provided, while economies of scale allow states to provide them at a lower cost.

TABLE 12-36: LOCAL CAPITAL EXPENDITURE NEEDS FOR NOMINAL CASE DEVELOPMENT, 1975-2000 (millions of 1975 dollars)

State	[illegible]			[illegible]			[illegible]			[illegible][a]		
	[illegible]	Schools[b]	Total[c]	[illegible]	Schools[b]	Total[c]	[illegible]	Schools[b]	Total[c]	[illegible]	Schools	Total
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Six States Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: [illegible]

[a] Note 10-year period, whereas others shown are 5 years each.

[b] At $1,000 per pupil.

[c] [illegible]

TABLE 12-37: ANNUAL OPERATING EXPENDITURES OF LOCAL GOVERNMENTS IN ENERGY AREAS OF SIX WESTERN STATES, 1980-2000 FOR NOMINAL CASE ENERGY DEVELOPMENT[a] (millions of 1975 dollars)

State	1980		1985		1990		2000	
	Total	Construction Related	Total	Construction Related	Total	Construction Related	Total	Construction Related
Colorado	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New Mexico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Montana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Dakota	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wyoming	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Six States TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	176.1	[illegible]	[illegible]	[illegible]

[a] Based on a figure of $1,000 per pupil for school costs derived from data in Mountain Plains Federal Regional Council; [illegible]

TABLE 12-38: ADDITIONAL ANNUAL CAPITAL AND OPERATING EXPENDITURES OF STATE GOVERNMENTS, 1980-2000, NOMINAL CASE ENERGY DEVELOPMENT
(in millions of 1975 dollars)

State	1980		1985		1990		2000	
	Total	Construction Related	Total	Construction Related	Total	Construction Related	Total	Construction Related
Colorado	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New Mexico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Montana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Dakota	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wyoming	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Six-States Total	77.1	30.6	104.1	29.4	307.8	38.3	908.0	279.8

As shown in this table, additional annual expenditures of over $900 million will be required by 2000. This is roughly comparable to the new expenses anticipated for local governments.

B. Revenues

If state governments tax individuals at current rates and also incur current per-capita costs, new energy developments can always be expected to provide a net surplus. This is because new revenue from conventional sources[1] approximately balance new costs while additional revenues will be available from special energy taxes.[2]

The principal taxes currently levied on energy production and conversion are summarized in Table 12-39. Applying these rates to the projected numbers of facilities in each state gives an estimate of energy-derived revenues (not counting conventional sources such as personal income taxes) for a typical year (1990) as shown in Table 12-40.

In the long run, state and local governments can be expected to derive more funds from new revenues than they expend on new costs. The only major exception is New Mexico, where new annual operating expenditures of the state are expected to exceed new revenues by

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[1] Mainly income and excise taxes.

[2] For example, Montana levies a 30-percent severance tax on coal mining.

TABLE 12-39: TAX RATES ON ENERGY EXTRACTION AND CONVERSION[a]

State	Property Tax[b,c]	Sales Tax[d] (percent)	Severance Tax (percent)	Energy Conversion Tax
Colorado	1.37	3 1/2	5 [d]	
New Mexico	1.22[e]	4		0.4 mill per kilowatt hour
Utah	1.82	4 3/4		
Montana	1.19[e]		30.5[f]	
North Dakota	1.48[g]	4	5.0[h]	0.25 mill per kilowatt hour and $0.10 per thousand feet[e]
Wyoming	1.52	4	3.5[i]	

Source: Detailed sources and further explanations cited in the corresponding local scenarios (Chapters 6-11).

[a] Royalty payments for federally owned coal are 12.5 percent in all states, 50 percent of which is returned to the state and local governments; on Indian Reservations, all royalties are retained by the tribe. Oil shale bonus bids of [illegible] million per plant are relevant to Colorado and Utah, assuming a size of [illegible] barrels per day per plant.

[b] Percent of actual cash value; rates prevailing in those counties studied in local scenarios (Chapters 6-11).

[c] Mostly to local government.

[d] Mostly to state government.

[e] Off-reservation only.

[f] 52.3 percent state, 47.7 percent local.

[g] Mines only.

[h] 40 percent local, 30 percent state, 30 percent saved.

[i] No loans to local government; interest to state.

TABLE 12-40: STATE AND LOCAL TAXES ON ENERGY FACILITIES, NOMINAL CASE DEVELOPMENT, 1990
(millions of 1975 dollars)

Receiving	Severance Taxes[a]	Mill Levies	Coal Royalties[a,b]	Sales and Use Taxes[c]	Conversion Taxes	Total
Colorado						
State	16.0		7.9	39.3		67
State for local[d]			3.6			3.6
Local		96.2		5.4		101.6
New Mexico						
State	2.1			1.9	7.4	11.4
State for local						
Local		0.1				0.1
Indian			10.6			10.6
Utah						
State			10.6	2.1		12.7
State for local			3.5			3.5
Local		55.2		.4		55.6
Montana						
State	283.8		87.2			371
State for local	303		36.1			339.1
Local	58.6	44				102.6
Indian			239.6			239.6
North Dakota						
State	18.9			20.8	30.6	70.3
State for local	22					22
Local	16.5	16.6			4.4	37.5
Wyoming						
State	4.3		38.2	10.6		53.1
State for local	0[e]		12.8			12.8[e]
Local		61.7		5.2		66.9
Region						
State	322.9		144	80.6	47	604.0
State for local	325		48			373
Local	55.1	289.8		9.3	4.4	306.6
Indian			263.0			263.3

Source: Table 12-39.

[a] Assuming mine-mouth value of coal = $11.38/ton (1975 currency).

[b] Assuming all coal in Utah federally owned, one-half of the coal in Colorado, Montana, Wyoming, none in New Mexico, North Dakota. Also assuming one-half coal in Montana and New Mexico on Indian reservations.

[c] Only on materials and equipment used in energy facility construction.

[d] Funds collected by the state but earmarked for discretionary allocation to impacted communities.

[e] But $209.4 million in accumulated loan funds available.

a margin of $23.5 million to $11.4 million. The margin for local government will be $27.8 million to $9.1 million.

There appear to be ample funds in each of the other states to meet new service demands. However, the local scenarios (Chapters 6-11) show that distribution problems will arise when population-impacted jurisdictions do not contain the energy facilities. In recognition of this problem, the "state-for-local" lines in Table 12-40 show the funds collected at the state level specifically for redistribution to impacted communities. Except for Colorado and New Mexico, these funds are probably sufficient to alleviate distributional problems.

Finally, Montana stands out from the other states in having a particularly large surplus. In fact, of the $2.08 billion likely to be collected in the six-state region, fully $1.55 billion is expected to be generated within Montana. Most of this will come from the 30-percent coal mine license tax, which is much higher than rates in any other state; Colorado has the next highest tax, which is 5 percent. Thus, there is at least the possibility that some mining companies will choose to locate in other states to avoid Montana's steep tax rate. In that case, the state's projected revenue would not be realized.[1]

12.4.5 Land Use

Changes in land use can be expected to occur as a consequence of the expected influx of population into the energy resource areas of the West. In addition to the obvious increases in urban land needs in cities and towns, some currently idle land will be converted to productive uses. There will be competition for level terrain for use as either cropland or urban development. In some cases, there will also be competition for the water being used for irrigation. For 53 sample counties in the U.S., new urban land use per capita ranged from 0.097 to 0.481 acre from 1961 to 1970, with an average of 0.173 acre.[2] Based on this average, estimates of the new urban land expected to be required by energy development in six western states are reported in Table 12-41.

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[1] On the question of taxes and other state legislation, see Christiansen, Bill, and Theodore H. Clack, Jr. "A Western Perspective on Energy: A Plea for National Energy Planning." *Science*, Vol. 194 (November 5, 1976), pp. 578-84.

[2] Zeimetz, Kathryn A., et al. *Dynamics of Land Use in Fast Growth Areas*, Agricultural Economic Report No. 325. Washington, D.C.: U.S., Department of Agriculture, Economic Research Service, 1976.

TABLE 12-41: NEW LAND REQUIREMENTS FOR ENERGY FACILITIES AND URBAN LAND FOR NOMINAL CASE, 1980-2000[a] (in acres and percent)

Year	Energy Facilities[b]	Urban Land	Total
COLORADO Garfield, Mesa, and Rio Blanco Counties (6,118,400 acres)			
1980	5,600 (0.09%)	312 (0.01%)	5,912 (0.10%)
1985	20,590 (0.34%)	3,079 (0.05%)	23,669 (0.39%)
1990	29,725 (0.49%)	5,986 (0.10%)	35,711 (0.58%)
2000	130,310 (2.13%)	41,658 (0.68%)	171,968 (2.81%)
Huerfano County Area (1,007,360 acres)			
1980	0	0	0
1985	28,000 (2.78%)	2,006 (0.20%)	30,006 (2.98%)
1990	28,000 (2.78%)	2,006 (0.20%)	30,006 (2.98%)
2000	28,000 (2.78%)	2,197 (0.22%)	30,197 (3.00%)
UTAH Kane and Garfield Counties (5,799,680 acres)			
1980	19,200 (0.33%)	1,107 (0.02%)	20,307 (0.35%)
1985	24,000 (0.43%)	1,658 (0.03%)	25,658 (0.45%)
1990	27,200 (0.47%)	2,111 (0.04%)	29,311 (0.51%)
2000	27,200 (0.47%)	2,214 (0.04%)	29,614 (0.51%)
Uintah and Grand Counties (5,228,160 acres)			
1980	0	0	0
1985	3,300 (0.06%)	104 (0.00%)	3,404 (0.07%)
1990	3,300 (0.06%)	104 (0.00%)	3,404 (0.07%)
2000	18,780 (0.36%)	4,671 (0.09%)	23,451 (0.45%)
NEW MEXICO San Juan, McKinley, and Valencia Counties (10,630,400 acres)			
1980	42,200 (0.40%)	1,090 (0.01%)	43,290 (0.41%)
1985	68,600 (0.65%)	2,526 (0.02%)	71,126 (0.67%)
1990	98,400 (0.93%)	3,564 (0.03%)	101,964 (0.96%)
2000	266,010 (2.50%)	9,377 (0.09%)	275,387 (2.59%)

TABLE 12-41: (Continued)

Year	Energy Facilities[b]	Urban Land	Total
Lea, Eddy, Roosevelt, and Chaves Counties (10,942,720 acres)			
1980	12,800 (0.12%)	1,713 (0.02%)	14,513 (0.13%)
1985	12,800 (0.12%)	2,232 (0.02%)	15,032 (0.14%)
1990	9,600 (0.09%)	1,194 (0.01%)	10,794 (0.10%)
2000	0	0	0
MONTANA Big Horn, Powder River, and Rosebud Counties (8,542,720 acres)			
1980	124,800 (1.46%)	2,006 (0.02%)	126,806 (1.48%)
1985	490,600 (5.73%)	9,238 (0.11%)	499,838 (5.84%)
1990	672,805 (7.88%)	12,940 (0.15%)	685,745 (8.03%)
2000	1,566,755 (18.34%)	37,212 (0.44%)	1,603,967 (18.76%)
NORTH DAKOTA Dunn, Mercer, McLean, and Oliver Counties (3,724,800 acres)			
1980	64,800 (1.74%)	1,211 (0.03%)	66,011 (1.77%)
1985	97,200 (2.61%)	2,422 (0.07%)	99,622 (2.67%)
1990	138,810 (3.73%)	3,702 (0.10%)	142,512 (3.83%)
2000	434,506 (11.67%)	14,636 (0.39%)	449,142 (12.06%)
Billings, Bowman, Hettinger, McKenzie, Slope, Stark, and Williams Counties (6,901,120 acres)			
1980	0	0	0
1985	64,800 (0.94%)	799 (0.01%)	65,599 (0.95%)
1990	97,200 (1.41%)	2,387 (0.03%)	99,587 (1.44%)
2000	326,055 (4.72%)	10,674 (0.15%)	336,729 (4.88%)
WYOMING Campbell County (3,043,840 acres)			
1980	172,400 (5.66%)	2,457 (0.08%)	174,857 (5.74%)
1985	224,800 (7.39%)	4,325 (0.14%)	229,125 (7.53%)
1990	294,000 (9.66%)	5,571 (0.18%)	300,871 (9.87%)
2000	572,930 (18.82%)	14,030 (0.46%)	586,960 (19.28%)

TABLE 12-41: (Continued)

Year	Energy Facilities[b]	Urban Land	Total
Johnson, Sheridan, Converse, Natrona, Carbon, Fremont, and Sweetwater Counties (28,070,400 acres)			
1980	9,900 (0.04%)	415 (0.00%)	10,315 (0.04%)
1985	33,000 (0.12%)	1,730 (0.01%)	34,730 (0.12%)
1990	42,900 (0.15%)	2,214 (0.01%)	45,114 (0.16%)
2000	373,915 (1.33%)	11,920 (0.04%)	385,835 (1.37%)

[a] Based on the following regional averaged land requirements:

underground coal mine (5 million tons per year)	5,600 acres
surface coal mine (lifetime usage) (5 million tons per year)	10,000 acres
3,000-megawatts-electric plant	2,400 acres
coal gasification plant	805 acres
coal liquefaction plant	2,056 acres
gas or oil production (100,000 barrels per day)	3,200 acres
uranium mine (surface)	3,000 acres
uranium mill	300 acres
oil shale mine (underground)	1,765 acres
oil shale retort facility (100,000 barrels per day)	1,200 acres

.173 acre of land per-capita additional permanent population.

[b] The estimates for energy facility land usage are high estimates based on information in the S&PP-Radian Energy Resource development Systems descriptions which will be distributed separately. The large overall quantities of land result from the projections of the Stanford Research Institute case (see Section 12.1).

As shown in that table, the energy facilities are the largest consumers of land. In the Nominal case level of energy development, by the year 2000 some areas in the Northern Great Plains states of Montana, North Dakota, and Wyoming would have 11-19 percent of the land taken by energy facilities, most of it now occupied by farms and ranches.[1] Reclamation, not considered in these estimates, could considerably reduce the overall land consumption. Land to be removed for such uses as rights-of-way and new rural roads is not included in the amounts listed in Table 12-41. The extent to which Indian lands will be included is not known, but large amounts are likely to be used in New Mexico and Montana.

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[1] The actual amount of land occupied by strip mines in the West through 2000 will be lower than the projections analyzed here, but the distribution will vary. Montana, for example, is likely to have far fewer mines than our analyses assumed.

12.4.6 Social and Cultural Effects

Agriculture and agricultural interests presently dominate much of the eight-state area that will be affected by energy resource development. The setting in the resource-rich parts of the region is primarily rural, with any urban population being limited to small towns. Local lifestyles and cultures associated with this western setting are likely to be changed by circumstances related to energy development, particularly where old-timers (i.e., natives) perceive themselves as being outnumbered by newcomers who hold different values and have different interests. Over time, the values and attitudes of the newcomers to the area could become dominant. The impact of projected large population shifts is especially acute when distinctive ethnic and/or religious groups are involved, such as Indians, Mexican-Americans, and Mormons.

Many of these impacts can be discussed within the context of social and cultural effects, or what is generally termed the "quality of life" under the more general rubric of the "human environment". In the past, economic indicators have often served to measure well-being, but more attention has recently been focused on other aspects.[1] In general, a person's sense of well-being will reflect his or her level of satisfaction with such things as: amount of leisure time; recreation facilities and opportunities for recreation; the quality of the physical environment; housing; food; social services; opportunities for education and training; personal safety and security; physical and mental health; transportation opportunities; and level of household income. Although difficult to assess, many of these variables may be perceived in a comparative sense, such as between neighbors or neighborhoods, or by comparing conditions in the past or perceptions of opportunities in the future. All these factors will likely be affected by energy development in the eight-state study area. However, different cultural groups will perceive attributes in different ways.[1] The lack of acceptance by many Indian nations of mining and similar activities is an example of cultural differences.

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[1] Arguments for the need to include measures of social as well as economic indicators of well-being received substantial impetus from Bauer, Raymond, ed. Social Indicators. Cambridge, Mass.: MIT Press, 1966 and from Olson, Mancur. Toward a Social Report. Washington, D.C.: Government Printing Office, 1969. For a more recent overall treatment of this idea, see U.S., Environmental Protection Agency. The Quality of Life Concept: A Potential Tool for Decision-Makers. Washington, D.C.: U.S., Environmental Protection Agency, 1973.

Factors impacting the quality of life for each of the site-specific scenarios (Chapters 6-11) and the nature of those impacts are listed in Table 12-42.[2] One of the most important variables in any estimation of quality of life impacts is the ability of the local government in each area to plan adequately for the various social, economic, and political impacts.[3] The capacity to plan and execute policies intended to address population-related impacts resulting from energy development varies throughout the West. For example, towns in North Dakota will probably need to institute full-time rather than part-time governments to insure that adequate planning and administration will continue. Conversely, our analysis of the Navajo/Farmington scenario indicated that a substantial capacity for planning exists but that local governments face potential revenue deficits. The other scenarios depict localities which either lack the resources or capacity to plan as well as to implement those plans.

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[1] A succinct treatment of perceptual indicators of the quality of life can be found in Andrews, Frank M., and Stephen Whitey, "Developing Measures of Perceived Life Quality," _Social Indicators Research_, Vol. 1 (May 1974), pp. 1-26. See also Stagner, Ross. "Perceptions, Aspirations, Frustrations, and Satisfactions: An Approach to Urban Indicators," _Annals of the American Academy of Political and Social Science_, Vol. 388 (March 1970), pp. 59-68.

[2] This table and discussion are based on a paper prepared for the Science and Public Policy-Radian team by Thomas James at the Mershon Center, Ohio State University.

[3] For a discussion of improving the quality of life through improved planning, see Case, Fred. "Social Indicators for Policy Planning," in _Proceedings of the Urban and Regional Information Systems Association Social Indicators Conference, Santa Monica, California, 1974_. Kent, Ohio: Kent State University, Center for Urban Regionalism, 1974; Galnoor Itshak. "Social Indicators for Social Planning." _Social Indicators Research_, Vol. 1 (May 1974), pp. 27-58; and Hauser, Phillip. "Social Goals as an Aspect of Planning," Exhibit II in U.S., Congress, Senate, Committee on Government Operations. _Full Opportunity and Social Accounting Act. Hearings_ before the Subcommittee on Government Research on S. 843, 90th Cong., 1st sess., Part 3, July 28, 1967, Appendix, pp. 445-54.

TABLE 12-4G: POTENTIAL IMPACTS ON THE QUALITY OF LIFE

[illegible]	[illegible]					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 12-42: (Continued)

[illegible]	[illegible]					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Since a substantial number of energy development-related impacts on individuals' lives are viewed as being negative, such developments can ultimately lead to a lowering of the quality of life. In many areas of the West, about half the current housing consists of mobile homes, and this trend will probably continue. Indications are that dissatisfaction with mobile home living will increase in conjunction with feelings of social segregation experienced by some construction workers and their families. The tension and stress precipitated by value and lifestyle conflicts between long-time residents and newcomers must also be taken into account.[1]

The problems and conditions mentioned above are not insurmountable, and the impact of the population in-flow on the quality of life will largely depend on the ability of local government and civic leaders to mobilize the long-time residents and the newcomers in a concerted effort to address the problems of concern to both groups. If this is not accomplished, or if cogent planning is deterred by local infighting, the quality of life of the people in the West can only be lowered.

Table 12-42 illustrates the variety of circumstances to be found at particular locations. The western Colorado and northwestern New Mexico areas appear to have the most easily handled types of problems. The major concern for western Colorado's oil shale region is a "beefing up" of the available planning capabilities so that a mechanism exists to deal with substantive problems. The area will have trouble delivering services during the early time periods, but relief will come when local governments begin to receive tax revenues from energy-related development. Some oldtimer/newcomer conflicts are to be expected in the short run, along with some dissension over the use or non-use of wilderness land. These and other problems could eventually lower the quality of life in the area unless proper attention is given to the impacts described.

The northwestern New Mexico area faces the possibility of revenue deficits for non-reservation governments, but substantial planning capacity to meet this problem is available. If any of the scenario areas can handle the problems associated

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[1] On quality of life issues related to the influx of new populations, see Wheaton, L.C., and M.F. Wheaton. "Identifying the Public Interest: Values and Goals," in Robinson, Ira, ed. Decision Making in Urban Planning. Beverly Hills, Calif.: Sage, 1972; and Hansen, George. "Information for Decision Makers," in Proceedings of the Urban and Regional Information Systems Association Social Indicators Conference, Santa Monica, California, 1974. Kent, Ohio: Kent State University, Center for Urban Regionalism, 1974.

with the possibility of insufficient revenue for complete service delivery, northwestern New Mexico should be the one. Compared to its experience with prior developments, Farmington should not experience much of an impact on its quality of life. Most of the impact will be felt by the Navajo reservation. Opposition to energy development is voiced by some Navajos because of the associated challenge to traditional values and living patterns. The overall standard of living of the Navajo would be increased through higher incomes, better housing and services, etc. On the other hand, raising the standard of living of the Navajo does not necessarily mean that their perceived overall quality of life is also enhanced. Nevertheless, the potential exists for a substantial segment of the area's population to increase their level of well-being, while the rest should at least be able to maintain their present levels of life quality. (Policy issues related to Indians are discussed at length in Section 14.5.)

The Southern Utah and North Dakota areas offer the best chance of energy development having a positive impact on the quality of life of area residents. Of the two, Southern Utah presents more serious problems. The major problem will be the conflict between the lifestyles of the rural Mormon residents and the more urban lifestyles of newcomers. A potential problem also stems from physical and visual pollution that could result in a negative economic impact by decreasing tourism in the area. Since over the long run revenues can be expected to provide a net budget surplus and housing and schools present no real problems (except a possible cash flow problem with the school systems), local officials can put most of their attention toward long-range planning for the area.

Likely energy development in the lignite-bearing area of North Dakota suggests a set of conditions where an increase in population will have a positive impact on the quality of life. The attitudes of the people now living in the area toward the energy development projects are favorable. Population has been decreasing since 1950, and energy development is viewed as a way to stop out-migration and bring new people into the area, including former residents of North Dakota who left for economic reasons. The removal of farmland from production and the conversion to strip mining will be difficult for some farmers to accept, but economic compensation as well as the creation of new jobs will be welcomed.

The Powder River Basin of Wyoming seems to have the highest potential in the West for an overall negative impact on its residents' quality of life. For example, Campbell County has been growing steadily since 1960, a 600-percent increase in population is anticipated between 1975 and 2000. The capability to plan for this increase exists but may not be used. Financial problems through 1985 and again after 1990 will put a severe strain on the services provided by local governments. The Gillette, Wyoming, area also has been documented as the site of child abuse and neglect on a large scale.[1]

In summary, the quality of life depends on reactions of people to their problems as well as on the problems themselves. Thus, more than any other factor in western energy development, quality of life is largely unaffected by mitigating measures from outside sources. Local activity, planning, and cooperation are among the most influential factors in quality of life assessments.

12.4.7 Political Impacts[2]

Although the population increases projected for this regional scenario are not large in most cases until the 1990-2000 decade, population growth in some states during that time will probably result in political changes. The populations of Montana, North Dakota, and Wyoming particularly will increase by as much as 50 percent. Much of the increase will arise from interregional migration. If the partisan preferences of newcomers to the region differ substantially from those of the natives, the partisan character of the entire region may shift.[3] Similarly, if the influx of newcomers changes the demographic composition of the region, the level of political participation may change as well.

The impact of construction workers on the region will differ substantially from that of operation and maintenance personnel. Construction workers will have the most immediate effect on the region. They will strain the medical, housing, recreation, and service facilities of the individual communities in the site area, which may call on the state and federal government for assistance. However, since the majority of construction workers are transients and many currently live in the region, they will probably not have any lasting political impact.[1]

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[1] Richards, Bill. "Western Energy Rush Taking Toll Among Boom Area Children." *Washington Post*, December 13, 1976, pp. 1, 4.

[2] This section is based on a paper prepared for the Science and Public Policy-Radian Research Team by Allyn Bross, Research Assistant, Department of Political Science, University of Oklahoma.

[3] Bone, Hugh A., and Austin Ranney. *Politics and Voters*. New York, N.Y.: McGraw-Hill, 1976; Campbell, Angus, *et al*. *The American Voter*. New York, N.Y.: Wiley, 1960, pp. 37-38. Historically, interregional migration has shifted the partisan loyalties of the western United States from heavily Democratic to bipartisan.

Operation and maintenance personnel will follow the construction workers and will have a more definite political impact because they will reside in the region on a long-term basis. Selected characteristics of the operations and maintenance workers can be summarized from the reports on individual energy production/conversion sites as follows: they are highly skilled in the technical and managerial fields needed to operate the energy production facilities; their income is above the median level for all individuals; and they are mostly between 30 and 60 years old. These characteristics are important in assessing the political impact of energy development because they are generally associated with a high level of involvement in politics.[2] Thus, operations and maintenance workers are more likely to become involved in community affairs than other groups. They will seek offices in the local government and in school, church, and civic groups.[3] If successful, these individuals are likely to use their leadership roles to guide the community's development according to their own values and priorities.

12.4.8 Materials and Equipment Availability

In obtaining the materials and equipment needed to develop energy resources in the western U.S., developers must compete with the materials and equipment needs of other regions and other industries. There is some question as to whether all of these needs can be met, particularly in the case of such items as large pressure vessels and draglines. The Environmental Protection

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[1] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[2] Lipset, Seymour Martin. Political Man. Garden City, N.Y.: Doubleday, 1960, p. 184; see also Pomper, Gerald. Voters' Choice. New York, N.Y.: Dodd Mead, 1975, Chapter 3; Flanigan, William H. Political Behavior of the American Electorate, 2nd ed. Boston, Mass.: Allyn and Bacon, 1972.

[3] There is a considerable body of literature available concerning the struggle for community power. The various theories are summarized in Keynes, Edward, and David M. Ricci, eds. Political Power, Community, and Democracy. Chicago, Ill.: Rand McNally, 1970. Coleman, James S. Community Conflict. New York, N.Y.: Free Press, 1957, is a dated but useful treatment of conflict in relatively small communities. Coleman says that citizens with a strong loyalty to the community are more likely to search for compromises than those with only a moderate commitment. See also Mayer, Robert R. Social Planning and Social Change. Englewood Cliffs, N.J.: Prentice-Hall, 1972.

Agency's Strategic Environmental Assessment System (SEAS) was used to investigate this question.[1] Assumptions within the SEAS model differ somewhat from those used by SRI and Bechtel in the interfuel competition and energy planning models discussed earlier. Consequently, no attempt was made to relate findings to the three SRI cases.

Two analyses were made using SEAS: the first called for expanded western energy development and, for comparative purposes, the second did not. The run simulating expanded development in the West provides for a level corresponding to SRI's High Demand case. This level was selected because the SEAS model only extends to 1985, whereas the major impacts of regional development are predicted by the SRI model to occur during the 1990-2000 decade. Thus, a higher demand case was chosen to expose possible problem areas which can be examined more closely using longer range modeling during the second and third years.

In the period to 1985, only three kinds of developments were considered as generating new economic activity: coal mining, coal-fired electrical generation, and uranium mining. Other energy development is not expected on a large scale before 1985, even in SRI's High Demand case. The assumed increments of production beyond 1975 levels are as shown in Table 12-43.

These increments have been added to the final demands of the respective industries. SEAS calculated the range of goods and services each industry will purchase to carry on at the expanded levels of production, the bills of goods coming from each of the supplying industries (for example, power shovel manufacturers buying steel), etc. Sectoral outputs for each of the two cases were then compared, and the net result of all economic "ripples" was determined.

Note that this analysis adds various amounts of western energy production to an economy which in other respects is carrying on "business as usual". If western energy was hypothesized to replace, rather than supplement, other energy supplies, then further analysis would be needed to describe the process of interfuel substitution. Moreover, SEAS treats all this development on a national scale, making no distinctions

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[1] For a summary description of SEAS, see Booz, Allen and Hamilton, Inc. Strategic Environmental Assessment System, Executive Summary, for U.S., Environmental Protection Agency. Bethesda, Md.: Booz, Allen and Hamilton, 1975. Briefly put, SEAS uses the input-output methodology to trace the ultimate economic effects of specified forces. Other components of the model, not used here, derive conclusions about environmental impacts.

TABLE 12-43: ADDITIONAL ENERGY DEVELOPMENT FROM THE WEST ASSUMED IN SEAS SIMULATION

Type of Energy Production	1975 National Production	1985 Western Increment	1985 Western Increment
Coal-Generated electricity	3.324 Q[a]	.683 Q	1.343 Q
Coal Mining (export)	$5.72 billion[b]	$1.14 billion	$2.91 billion
Uranium Mining[c]	$1.05 billion	$1.05 billion	$2.53 billion

[a] Quadrillions of British thermal units (10^{15}).

[b] All money figures in 1971 currency.

[c] These demands added to the category of nonferrous, noncuprous metal ores.

about the location of economic activity.[1] Finally, this analysis only extends backwards in the industrial chain (from the mining company to its vendors, etc.). The analysis answers the question "what materials and equipment must be produced to achieve the western energy development called for by the high demand regional scenario?" but does not trace the disposition of such energy. For example, coal exported from the region will be burned by utilities, by steel companies, by Canadians and Japanese, etc. Except for the run performed to trace such effects as far as electricity generation (reported below), energy consumption was excluded.[2]

A. Economywide Variables

Certain variables summarize the overall pace of economic activity in the nation. Of these "macro economic" variables, the ones most strongly affected by western energy are shown in Table 12-44.

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[1] To simulate increased western production within the Strategic Environmental Assessment System, the coal mining/rail transport coefficient was boosted by a factor of 1.84 to reflect the longer haul to eastern markets. This had the effect of increasing supply from western sources.

[2] Railroad transportation was included, even though it occurs "downstream" of mining, industrially speaking, due to a quirk of the Strategic Environmental Assessment System. In point of fact, the impact on railroads will be substantial.

TABLE 12-44: ECONOMIC VARIABLES MOST AFFECTED
BY ENERGY DEVELOPMENT

Economic Category	1983			1985		
	Base Case	Energy Development Case	Percent Difference	Base Case	Energy Development Case	Percent Difference
Unemployment Rate (percentage)	4.67	4.30	-7.91	4.11	3.58	-12.77
Inventories (billions of dollars)	17.59	18.14	+3.10	10.85	11	+ 1.38
Equipment Investment (billions of dollars	153.6	155.1	+0.96	161.9	163.5	+ 0.97
Construction Investment (billions of dollars)	116.2	117.2	+0.86	129.8	131.3	+ 1.13

Source: Strategic Environmental Assessment System, Environmental Protection Agency.

In proportional terms, the unemployment rate will be the most strongly affected variable. The High Demand case could reduce the national rate by 0.5 percentage points by 1985 (over what it otherwise would be). However, the two cases were modeled so as to make western development an "autonomous" increase in aggregate demand. In reality, such development would recruit many workers from other industries, not just from the ranks of the unemployed.[1]

Most equipment purchases are accounted for directly by mining industries, most construction directly by electric utilities. The sectors most strongly affected by induced changes will be the railroad industry and its suppliers. These effects are discussed below in the analysis of impacts on specific sectors of economic activity.

B. Industry Outputs

Whereas western energy development can be expected to increase Gross National Product by about 0.5 percent, certain sectors[2] are likely to respond much more than others. The largest changes can be expected to occur in those sectors representing the actual western energy development. Together with feedback effects, these are postulated to grow as follows by 1985: other nonferrous ores due to uranium mining by 148.5 percent; coal mining by 47.2 percent; and electric utilities by 8.9 percent. The output of these three industries in 1985 would be $13.3 billion (1971 currency) greater under the High Demand case than it would be in 1985 under the Base case. The model calculates that, as a result of this impulse, $21.8 billion of outputs would be induced in other sectors. The sector groupings that would be most strongly affected are transportation (+3.93 percent) and non-electric utilities (+2.19 percent). Manufacturing as a whole would grow 0.76 percent larger than it otherwise would by 1985. However, particular sectors would experience considerably greater stimulus, as detailed in Table 12-45.

With expanded energy development in the West, the railroad industry can be expected to grow 16 percent larger than it otherwise would by 1985. Together with its equipment manufacturers, the industry must supply an output greater by $4.9 billion. In

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[1] Looked at from the manpower point of view, employment rates will be less affected than unemployment. By 1985, employment would differ by about 560,000 jobs, which is only 0.5 percent of the aggregate. Details on skilled occupations may be found in Section 12.4.9.

[2] Strategic Environmental Assessment System classifies the economy into 185 sectors.

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TABLE 12-45: DIFFERENCES IN OUTPUTS BETWEEN BASE
CASE AND HIGH ENERGY DEMAND CASE,
INDUSTRIES MOST AFFECTED, 1980 and 1985

Industrial Category	1980		1985	
	Percent Change	Dollar Change (millions)	Percent Change	Dollar Change (millions)
Railroads	7.56	1,690	15.92	4,020
Railroad equipment	7.50	406	15.91	859
Transformers and switchgear	4.46	248	3.86	259
Engines and turbines	3.28	260	4.10	404
Construction machinery	2.55	247	4.49	460
Natural gas	2.52	540	2.79	640
Bearings	2.02	51	3.50	100
Water transport	1.92	66	3.62	128
Industrial controls	1.87	54	1.98	64
Pumps and blowers	1.79	92	2.17	114

Source: Strategic Environmental Assessment System, Environmental Protection Agency.

light of the chronic difficulties which have plagued railroads, it will be difficult for them to expand to meet this requirement. A few companies would probably handle most of the new traffic: Burlington-Northern, Chicago and Northwestern, Union Pacific, Denver and Rio Grande Western, and Sante Fe. (Transportation is discussed in more detail in Section 12.9.)

Substantial new supplies of mining and earth-moving machinery must be produced to support the mining activities required by expanded energy production. A variety of "nuts and bolts" industries, such as ball and roller bearings, machine shops, etc. would also be affected. While the effect does not seem large on the aggregated level, bottlenecks may occur with special products. For example, the steel industry would be expected to grow only 2.2 percent larger than the Base case by 1985, but the subsector of steel foundries (representing about 2 percent of the whole sector) would have to increase by 10.2 percent. Within the foundry subsector, only a few firms can make items like large pressure vessels. The result could be extended backlogs and construction delays for particular items.

Large pressure vessels exemplify the kinds of bottlenecks which may occur. While "numerous nuclear reactors and petroleum vessels have been constructed in these heavier thicknesses"[1] (13-inch steel walls), many coal conversion vessels will be the heaviest pressure vessels ever built—up to 3,000 tons. Also, technological problems may arise, as well as backlogs in material supplies. For example, heavy plates are only available from one domestic source and two foreign sources.

Finally, the natural gas industry would be noticeably impacted, to the extent of 1.36 billion cubic feet per day greater demand more under the the High Demand case in 1985. (All this production is induced in support of other sectors, rather than being assumed in the scenario definition. Thus, some appreciation is gained of the fact that "it takes energy to get energy.")

C. Capital Investment

Generally speaking, those industries which would be called on for the largest expansion of output are those which must expand their capital base the most. In proportional terms, the industries which must accelerate their rate of investment the most[2] in 1985 are: railroads (20.3 percent), railroad equipment (12.5 percent), engines and turbines (5.6 percent), electric instruments and transformers (4.4 percent), and general industrial machinery (2.5 percent).

For the economy as a whole, more than $1.5 billion in new investment in 1985 would be induced by the High Demand case (not counting mining and utilities). In terms of absolute amounts, the most affected industries would be: railroads ($659 million), communication ($120 million), finance and insurance ($80 million), iron and steel ($41 million), and construction ($41 million). Most of these sectors would be basic to any expansion of economic activity.

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[1] Hicklen, William. "The Construction of Coal Conversion Vessels," in Papers: Clean Fuels from Coal Symposium II. Chicago, Ill.: Institute of Gas Technology, 1975, pp. 795-816.

[2] This is measured as the difference between the levels of development in annual rate of new investment.

D. Geographic Distribution of Impacts

SEAS can be used to determine where these activities will take place. In making this determination, each region is assumed to change its share of each industry's national output in accordance with OBERS projections.[1] Major shifts of activity, such as coal mining moving westward, are not assumed by such forecasts. Certain regions grow faster than others mainly because they contain faster growing industries.

SEAS' regionalization module for a sample of 16 metropolitan areas shows that four would be particularly affected (on a proportional basis): Birmingham, Alabama; Pittsburgh, Pennsylvania; Salt Lake City, Utah; and Duluth-Superior, Minnesota-Wisconsin. Birmingham's total output would be 4.02 percent greater by 1985, compared to a national average impact of 1.13 percent.[2]

Each of the other impacted cities can be expected to grow via varying combinations of industries. The largest components of growth are shown in Table 12-46.

E. Electricity Impacts

As described to this point, the analysis considers only the fate of coal and uranium transported as raw resources. But most of these materials would ultimately be used in the production of electricity.[3] To obtain some indication of the consequences of fuel consumption, SEAS was run with a third scenario which adds enough electrical generation to the Base case to consume the mined fuels. SEAS then implicitly attributes the appropriate rates of mining activity, transportation, etc. However, in contrast to the High Demand case described above, SEAS also calculates the total requirements of a significantly expanded utility

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[1] U.S., Department of Commerce, Bureau of Economic Analysis and Department of Agriculture, Economic Research Service. *1972 OBERS Projections: Economic Activity in the U.S., Vol. 4: States*, for the U.S. Water Resources Council. Washington, D.C.: Government Printing Office, 1974.

[2] Each of these cities will grow for different reasons. Salt Lake's case seems to be spurious: two-thirds of their growth is caused by "other nonferrous" (and noncuprous) ores. This industry was augmented externally to model uranium mining, but the Salt Lake area produces many "other" metals as by-products of copper mining. For example, the Bingham copper mine qualifies as the nation's second largest gold mine by virtue of the extraction of that "impurity".

[3] Electricity generation has been considered above only to the extent that conversion takes place within the West.

TABLE 12-46: LOCATION OF ECONOMIC GROWTH INDUSTRIES

Location	(Millions of Dollars) Growth
Birmingham, Alabama	
Railroad equipment	$91.2
Steel	16.9
Wholesale trade	4.1
Structural metal products	3.3
Cement, gypsum	1.1
All sectors	$129
Pittsburgh, Pennsylvania	
Steel	$99
Railroad equipment	53.3
Wholesale trade	12
Structural metal products	6.2
Construction and mining equipment	4.4
All sectors	$215
Duluth-Superior, Minnesota-Wisconsin	
Iron mining	$12.6
Steel	2.2
Construction and mining equipment	
Wholesale trade	1
Railroad equipment	0.6
All sectors	$20.5

industry. Specifically, electricity demands were assumed as follows:

	1980, Quadrillion Btu	1985, Quadrillion Btu
Electricity by coal	1.93	4.11
Electricity by uranium	1.68	4.07

The results of SEAS' analysis of this third case indicate that electrical generation would have larger impact on the economy than mining, transportation, and mine-mouth generation. About $37.6 billion of outputs would be induced in 1985, as compared to $17.8 billion in the "all western" scenario.

An examination of the industries most affected (Table 12-47) shows a greater representation of electrical-oriented sectors,

TABLE 12-47: DIFFERENCES IN OUTPUTS BETWEEN BASE CASE AND HIGH ENERGY DEMAND WITH ELECTRICAL GENERATION, INDUSTRIES MOST AFFECTED, 1985

Industry	Increase in Output (millions of dollars)	Percent Change
Transformers and switchgear	1,383	20.61
Railroad equipment	840	15.55
Railroads	3,900	15.44
Engines and turbines	1,284	13.10
Pottery	122	9.30
Structural metal products	1,800	7.97
Nonferrous wire drawing	496	7.91
Lighting and wiring equipment	674	6.94
Industrial controls	221	6.85
Construction and mining equipment	620	6.13

SOURCE: Strategic Environmental Assessment System, Environmental Protection Agency.

even of "pottery", which apparently reflects the need for ceramic insulators. The railroad sector shows almost exactly the same effect as in the previous cases.

12.4.9 Personnel Resources Availability

The question of personnel availability is addressed primarily on the regional and national levels because it is unlikely that local communities in the West will be able to fill the skilled positions required by the energy technologies.[1] The unskilled positions could largely be met locally but these would hardly lead to bottlenecks in any case. From the manpower supply point of view, the critical question is whether rapid energy development could be delayed by a nationwide shortage of key skilled personnel.

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[1] In a recent survey, 73.9 percent of the professional, technical, and supervisory workers were found to be of non-local origin. See Mountain West Research, Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 19.

A. Levels of Development

As with the analysis of financial resources, the overall pace of development is considered first. Manpower needs are based on the SRI Nominal case projection and on the technical and skilled manpower resources for standard-size facilities as detailed in the Bechtel Energy Supply Planning Model.[1] Taking a 3,000-MWe (megawatts-electric) mine-mouth power plant as an example, operation and maintenance will require a work force of: 24 engineers (16 electrical, 8 mechanical), 4 draftsmen, 56 supervisors, 240 skilled tradesmen (80 equipment operators, 80 welders, 48 electricians, and 32 pipefitters), and 112 relatively unskilled workers.

B. Operations

The total number of workers required for operating the numbers of plants in the Nominal case detailed by skill category, is listed in Table 12-48. In terms of supply, the most readily available source of labor would be those workers filling similar positions in similar industries. If this source is orders of magnitude greater than western energy requirements, then western development should have relatively little impact in the labor market. On the other hand, if needs are large in comparison to supply, then other industries must be raided, workers upgraded, standards lowered, etc.

This analysis is focused on the next decade because almost any degree of demand could be met by specific training, within 10 years.[2] Although special provisions might be required for schools, apprenticeship programs, etc., supply would not be absolutely constrained by the current skill distribution beyond about 1985.

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[1] Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976; Carasso, M., *et al.* *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

[2] A recent environmental impact statement which detailed the qualifications of the labor force indicated no more than 10 years experience is required for any of the positions. See U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

TABLE 12-48: DEMAND FOR SKILLED AND PROFESSIONAL PERSONNEL, WESTERN REGION, POST-1975 FACILITIES (operation and maintenance)

Occupation	1980	1985	1990	2000
Engineers				
Chemical		30	200	1,500
Civil		0	30	300
Electrical	150	270	390	800
Mechanical	90	180	320	900
Mining	90	210	370	900
Geological	10	30	70	200
Other	60	160	280	700
Total Engineers	400	880	1,660	5,300
Draftsmen	130	290	490	1,200
Supervisors	1,680	3,390	5,670	12,200
Other Technical	890	1,950	3,490	8,700
Total Managerial and Technical	2,700	5,630	9,650	22,100
Pipefitters	260	530	1,020	3,900
Electricians	1,240	2,500	4,180	9,400
Boilermakers		20	130	1,000
Carpenters		60	20	1,400
Welders	700	1,360	2,090	4,900
Operatives	3,600	8,590	16,400	50,100
Underground Miners	2,610	4,920	9,540	22,400
Other Skills and Crafts	4,440	10,670	20,460	60,600
Total Skills and Crafts	12,850	28,650	53,840	153,700
All Technical, Managerial, and Skilled	15,950	35,160	65,350	181,100

SOURCE: Carasso, M., *et al. The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, et al. *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

The 1970 census report on "Occupations by Industry" was consulted to determine the characteristics of the labor force in the mining and utility industries. The 1985 personnel requirements, expressed as a percentage of this readily available pool, are indicated in Table 12-49. As shown in that table, labor requirements for developing western energy resources could range up to about 12 percent in some of the occupational categories, but for most occupations the demand would be less than 5 percent of available supply. The 11.9 percent indicated for operatives may actually be less because some 100,000 workers were deducted from this category and classified as "underground miners". Resolution of this question must await the collection of more detailed data.

Western energy may tighten the markets for technicians, mining engineers, and welders, with 1985 demand exceeding 8 percent of the readily available labor pool in each case. The technician category consists mainly of surveyors, instrumentation people, and chemical laboratory people.

Western development may noticeably raise salaries, perhaps as much as 20 percent. It may also provide the opportunity for further unionization in the West. Some skilled technicians (e.g., welders) can be easily transferred from other industries, while those such as mining engineers must take college courses and gain specific job experience over several years. Some movement toward mining engineering can already be detected.[1]

As noted previously, the major long-term limitation is not the current shape of the labor force but the training programs which are or are not instituted. In particular, the 1985-2000 period will bring very rapid increases in the demand for chemical and civil engineers, boilermakers, and carpenters. Clearly, new engineers must, at some point, go through a college curriculum, some all the way through advanced degrees. Conversely, skilled manual trades are learned primarily by "hands on" experience. Therefore, the former can be promoted via student scholarships and grants to colleges[2] and the latter through simulated mines

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[1] The Bureau of Mines reports that college enrollments in that field have risen 22 percent in the past year. Poe, Edgar. "In Washington." Coal Mining and Processing, Vol. 13 (April 1976), pp. 39-42.

[2] In the 94th Congress, a bill (S62) to provide 1,500 "energy resource graduate fellowships" for each of the next 5 years was introduced. Bureau of National Affairs. "Coal: Administration Witnesses Oppose University Labs, Energy Resource Fellowships." Energy User's Report, Current Developments No. 117 (November 6, 1975), pp. A-34 through A-40.

TABLE 12-49: 1985 WESTERN ENERGY DEMAND FOR OPERATIONAL LABOR AS PERCENTAGE OF 1970 NATIONAL MARKET[a]

Occupation	1985 Western Demand[b]	1970 Supply[c]	Percentage
Engineers			
Chemical	30	5,800	0.5
Civil	0	1,300	0
Electrical	270	18,600	1.5
Geological[d]	30	2,100	1.4
Mechanical	180	4,400	4.1
Mining	210	2,500	8.4
Other	160	4,100	3.9
Total Engineers	880	38,800	2.3
Draftsmen	290	8,200	3.5
Supervisors	3,390	48,100	7
Other Technical	1,950	18,400	10.6
Total Managerial and Technical	5,630	74,700	7.5
Pipefitters[e]	530	10,500	5
Electricians[f]	2,500	100,200	2.5
Boilermakers	20	1,400	1.4
Carpenters	60	8,000	0.8
Welders[g]	1,360	16,400	8.3
Underground Miners[h]	4,920	112,100	4.4
Operatives[i]	8,590	72,300	11.9
Other Skills and Crafts	10,670	226,700	4.7
Total Skills and Crafts	28,650	547,600	5.2

[a] This table tabulates the number of workers in the following census industry categories: mining, excluding oil and gas production; privately-owned electric utilities; and petroleum refining.

[b] Source: Table 12-48.

[c] Source: U.S., Department of Commerce, Bureau of the Census. Occupation by Industry, Subject Report PC(2)-7C. Washington, D.C.: Government Printing Office, 1973, Table 8.

[d] Census category: geologists.

[e] Census category: plumbers and pipefitters.

[f] Census category: electricians and linemen.

[g] Census category: welders and flamecutters.

[h] Census categories: blasters and powdermen, butting operatives, earth drillers, mine operatives N.E.C., motormen.

[i] Nontransport operatives, excluding distinctly mining categories.

and other such specially designed facilities.[1] In short, foreseeable labor requirements can be met but some will require expanded training programs, union cooperation, etc.

C. Construction

The same basic methodology was used in the analysis of construction requirements. The census categories of "general contractors except buildings" and "special trades contractors, salaried employees" were used because they correspond roughly to what is generally known as "heavy construction". On the demand side, the Bechtel data base indicates the number of construction workers needed in each year leading up to the completion of each energy facility. For simplicity, the average number of workers in each year of major construction activity was multiplied by the number of plants in that phase at any given time. The total numbers employed in selected years are given in Table 12-50.

When 1985 demands are compared with the size of the construction labor force (Table 12-51), potential shortages of mining engineers, boilermakers, and chemical engineers are even greater than the projected problems with operation and maintenance personnel.

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[1] For example, Tillman, David A. 'Peabody Training Center Simulates Real Underground Conditions." Coal Mining and Processing, Vol. 12 (December 1975), pp. 62-67.

TABLE 12-50: DEMAND FOR SKILLED AND PROFESSIONAL PERSONNEL, WESTERN REGIONAL (construction workers)

Occupation	1980	1985	1990	2000
Engineers				
Chemical	30	270	760	3,200
Civil	740	970	1,550	5,300
Electrical	450	580	1,020	3,500
Mechanical	410	700	1,350	5,200
Mining	100	190	260	600
Geological	40	80	110	400
Other	70	200	420	1,700
Total Engineers	1,840	2,990	5,470	19,900
Technicians				
Draftsmen	900	1,720	3,520	9,100
Supervisors	430	710	1,270	4,700
Other Technical	1,870	2,980	5,460	19,800
Total Managerial and Technical	3,200	5,410	10,250	33,600
Skilled Trades				
Pipefitters	2,640	5,660	12,540	50,800
Electricians	1,780	2,500	4,540	16,800
Boilermakers	1,620	1,600	2,340	7,700
Ironworkers	1,120	1,430	2,320	7,700
Carpenters	1,060	1,760	3,300	12,900
Operating Engineers	1,790	2,870	4,650	16,000
Welders	1,640	2,480	4,900	18,700
Other Skills and Crafts	1,150	1,440	2,150	6,500
Total Skills and Crafts	12,800	19,740	36,740	137,100
All Technical, Managerial, and Skilled	17,840	28,140	52,460	190,600

Source: Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

TABLE 12-51: 1985 WESTERN ENERGY DEMAND FOR CONSTRUCTION LABOR AS PERCENTAGE OF 1970 NATIONAL MARKET

Occupation	1985 Western Demand	1970 Supply	Percentage
Engineers			
Chemical	270	900	30
Civil	970	54,800	1.8
Electrical	580	4,800	12.1
Mechanical	700	4,300	16.3
Mining	190	100	190
Geological	80	500	16
Other	200	6,900	2.9
Total Engineers	2,990	72,300	4.2
Technicians			
Draftsmen	1,720	16,000	10.8
Supervisors	710	158,500	0.4
Other Technical	2,980	28,000	10.6
Total Technicians	5,410	197,500	2.7
Skilled Trades			
Pipefitters	5,660	174,100	3.3
Electricians	2,500	182,700	1.4
Boilermakers	1,600	2,600	61.5
Ironworkers[a]	1,430	44,800	3.2
Carpenters	1,760	133,000	1.3
Operating Engineers[b]	2,870	22,800	12.6
Welders	2,480	38,100	6.5
Other Skills and Crafts	1,440	822,100	0.2
Total Skills and Crafts	19,740	1,420,200	1.4

Source: Table 12-50 and U.S., Department of Commerce, Bureau of the Census. Occupation by Industry, Subject Report PC(2)-7C, Washington, D.C.: Government Printing Office, 1973, Table 8.

[a] Census categories of cranemen and hoistmen and structural metal craftsmen.

[b] Census categories of earth drillers, miscellaneous machine operatives, and fork lift operatives.

TABLE 12-52: 1985 WESTERN ENERGY DEMAND FOR SELECTED OCCUPATIONS IN CONSTRUCTION, MINING, PETROLEUM REFINING, AND ELECTRIC UTILITIES

Occupation	1985 Demand	1970 Labor Pool	Percentage
Mining Engineers	400	3,100	12.9
Boilermakers	1,620	6,600	24.5
Chemical Engineers	300	8,200	3.7

Source: Table 12-48 and 12-50 and U.S., Department of Commerce, Bureau of the Census. *Occupation by Industry*, Subject Report PC(2)-7C. Washington, D.C.: Government Printing Office, 1973, Table 8.

If the demands and supplies for these occupations are combined for construction, mining industries, petroleum refining and electric utilities, the results are as shown in Table 12-52.

It appears that chemical engineers would not be a problem but that boilermakers could constitute a significant bottleneck. Additional workers could be recruited from manufacturing industries, but ultimately apprenticeship programs must be expanded. Even if the 1985 demand is met from the current labor pool, a five-fold increase beyond the 1985 demand is anticipated by 2000 (7,710 in construction versus 1,600 at the earlier date).[1]

Beyond 1985, labor requirements would be greatly increased by gasification and shale oil plants. Particularly sharp growth in demand (seven-fold or more) would be felt by chemical and mechanical engineers, pipefitters, welders, and carpenters. As noted previously in the case of operations personnel, a long lead time would allow these requirements to be met but would necessitate early expansion of formal schooling and/or apprenticeship programs.

Western energy is still an emerging industry; thus, the future course of industrial relations has not yet been established. As the industry grows, it will obviously provide a major opportunity for union organization.[2] What is considerably less clear is how far labor organization will go and what forms it might take. For example, the historical patterns of Appalachian mining will not necessarily be repeated. Almost all western mining is done by surface methods, which call for a smaller, more educated workforce; there is more capital per worker than in underground mines; the work is safer; etc. All these features have a bearing on the pace and form of unionization. Moreover, the energy conversion facilities have small, highly specialized workforces. In short, western energy does not seem easily organizable into the type of industrial union seen in the East, but a number of organizations will undoubtedly try to establish themselves.[1] The results cannot be predicted with any reliability.

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[1] Note that the demand shifts from building power plants (95.0 percent of the boilermakers in 1980) to gasification and shale oil plants (59.0 and 38.4 percent respectively in 2000).

[2] Right-to-work laws in some western states may prevent this to some extent.

12.4.10 Capital Availability

A. Capital Requirements

Large investments would be required to develop western energy resources at any of the three levels being considered. Nationwide, investments would be even larger and questions have been raised about the ability and willingness of financial institutions to undertake such extensive commitments.

In this subsection, an attempt is made to answer several of these questions, specifically:

1. How large are the demands for capital implied by the western energy scenario? What is the time distribution of these demands?
2. Is this demand for capital "large" compared to national markets, in the sense of raising interest rates, diverting substantial funds from other sectors, etc?
3. Are the individual projects "large" compared to the credit limits of firms in the industry? Will western energy development alter current patterns of industrial organization?
4. How sensitive are these forecasts to changes in market conditions?

Oil shale can be used to illustrate how questions about financial resource availability may be answered because the pattern of growth anticipated for oil shale is simpler than the growth pattern of some other resources. When the SRI model was constructed, it appeared that oil shale development would begin at a slow rate in the 1980's and accelerate rapidly to 2000 and beyond. This would result in investment expenditures that grow exponentially, while the resulting return flow of cash lags behind and has relatively little impact until after 2000.

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[1] Recent western organizing efforts of the United Mine Workers are described in Business Week, April 18, 1977.

Using the Bechtel Energy Supply Planning Model data for a 100,000 barrels per day plant operating at 90-percent efficiency, the investment required during construction for each plant will be $957 million. Annual return cash flow after operation begins and after dividends are paid out will amount to $54 million per plant. Combining these positive (into the project) and negative (back from the project) flows of money for the entire sequence of plants coming on stream through 2005, the graph in Figure 12-3 results.

These data include all plants opening by 2005 because pre-start-up construction causes substantial impacts before 2000. The industry is just beginning a state of extremely rapid growth during 2000-2010. As a result, investment expenditures far outpace the growth of return cash flow well into the next century.

The coal gasification case produces similar results. Gasification and oil shale would require the largest share of capital going to western energy development in the 1990's. However, the pace of gasification development would begin to moderate slightly by 1999 (Figure 12-4), return cash flow would start catching up, and net capital demand would peak out at $6.3 billion per year.

Two other technologies contribute to capital demands during the time frame of this study: surface coal mining and mine-mouth power generation (Figures 12-5 and 12-6). Financial data for all these industries are summarized by 5-year periods in Table 12-5). The patterns of development are quite diverse. Whereas oil shale and gasification are young and growing industries, mining is characterised by a steady (almost linear) growth of output, and mine-mouth power plants will have achieved a "mature" industry status by the late 1980's with only slight growth afterwards. Oil shale and gasification require steadily growing inputs of capital, while mining requires a fairly constant $250 million in new money per year. Also, with a number of new plants coming on-stream in the opening years of the study period, mine-mouth power will actually become a net supplier of funds by 1985. (These funds could be used directly by the utilities for other types of projects or else for paying off bonds and other debts. In either case, they will relieve the capital markets of that much demand.)

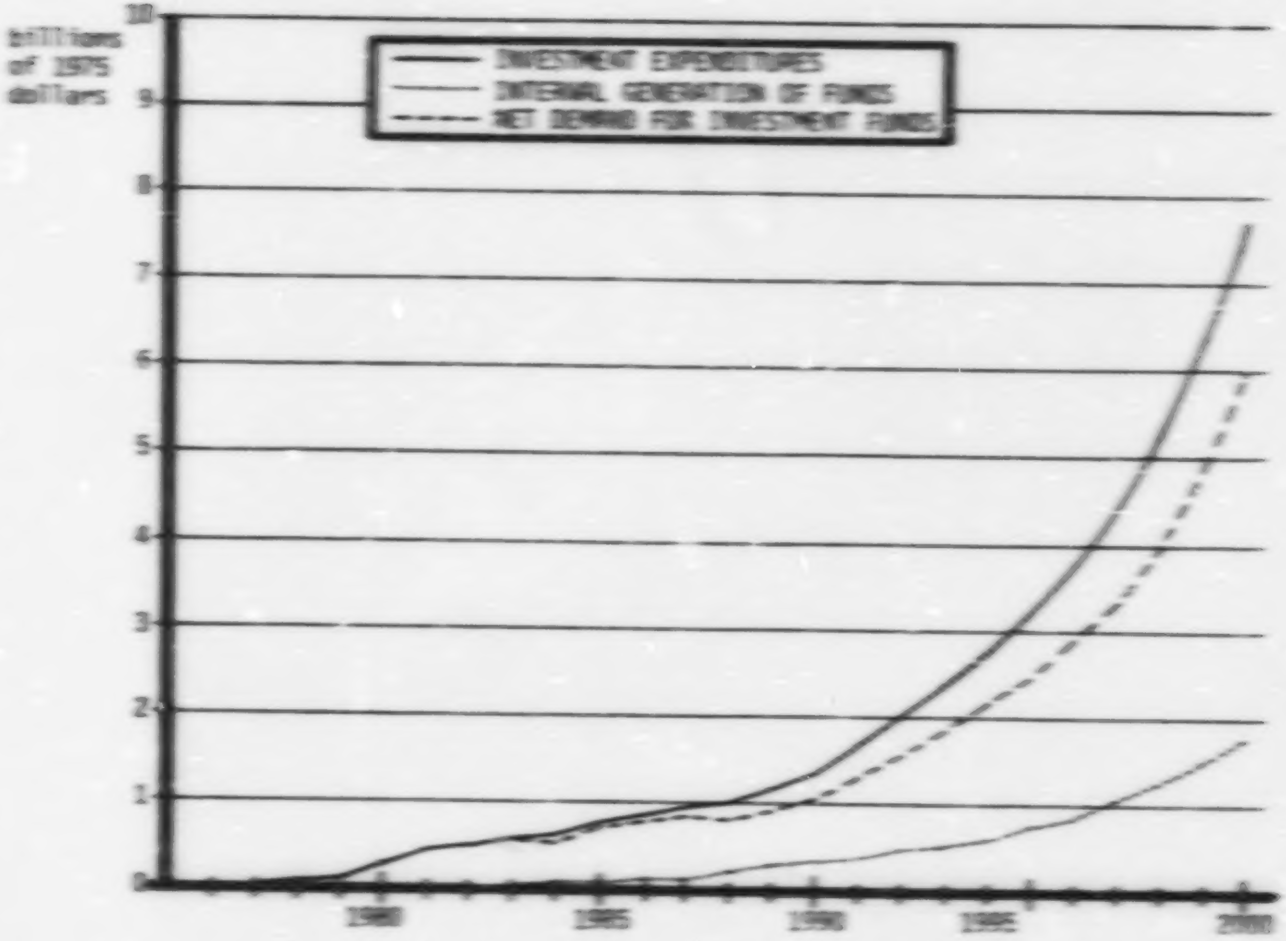

FIGURE 12-3: OIL SHALE (MINE, RETORT, AND UPGRADE), CASH FLOW, ANNUAL, ALL PLANTS OPENING DURING 1976-2005

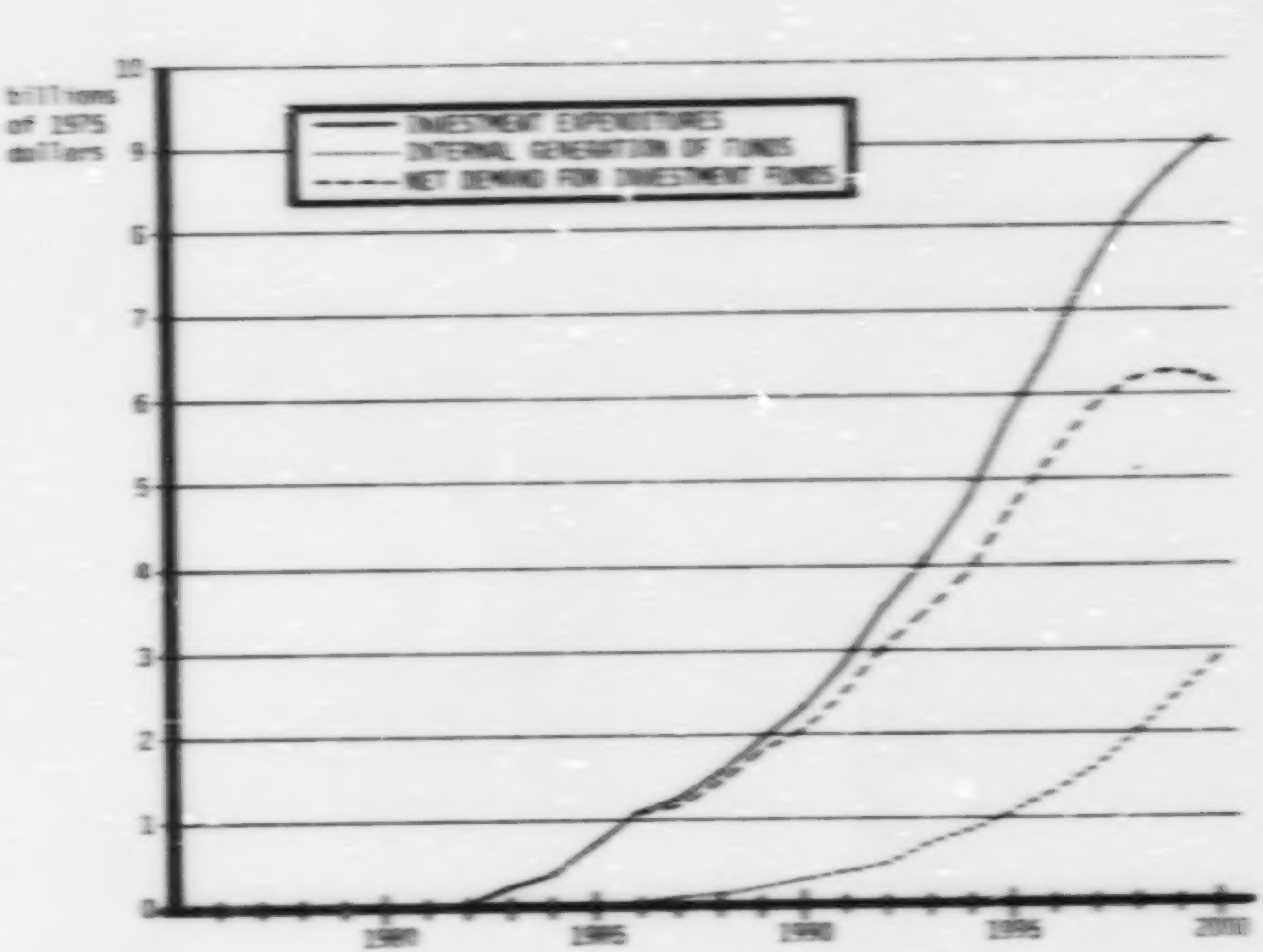

FIGURE 12-4: COAL GASIFICATION PLANTS, CASH FLOW, ANNUAL, ALL PLANTS
OPENING 1976-2004

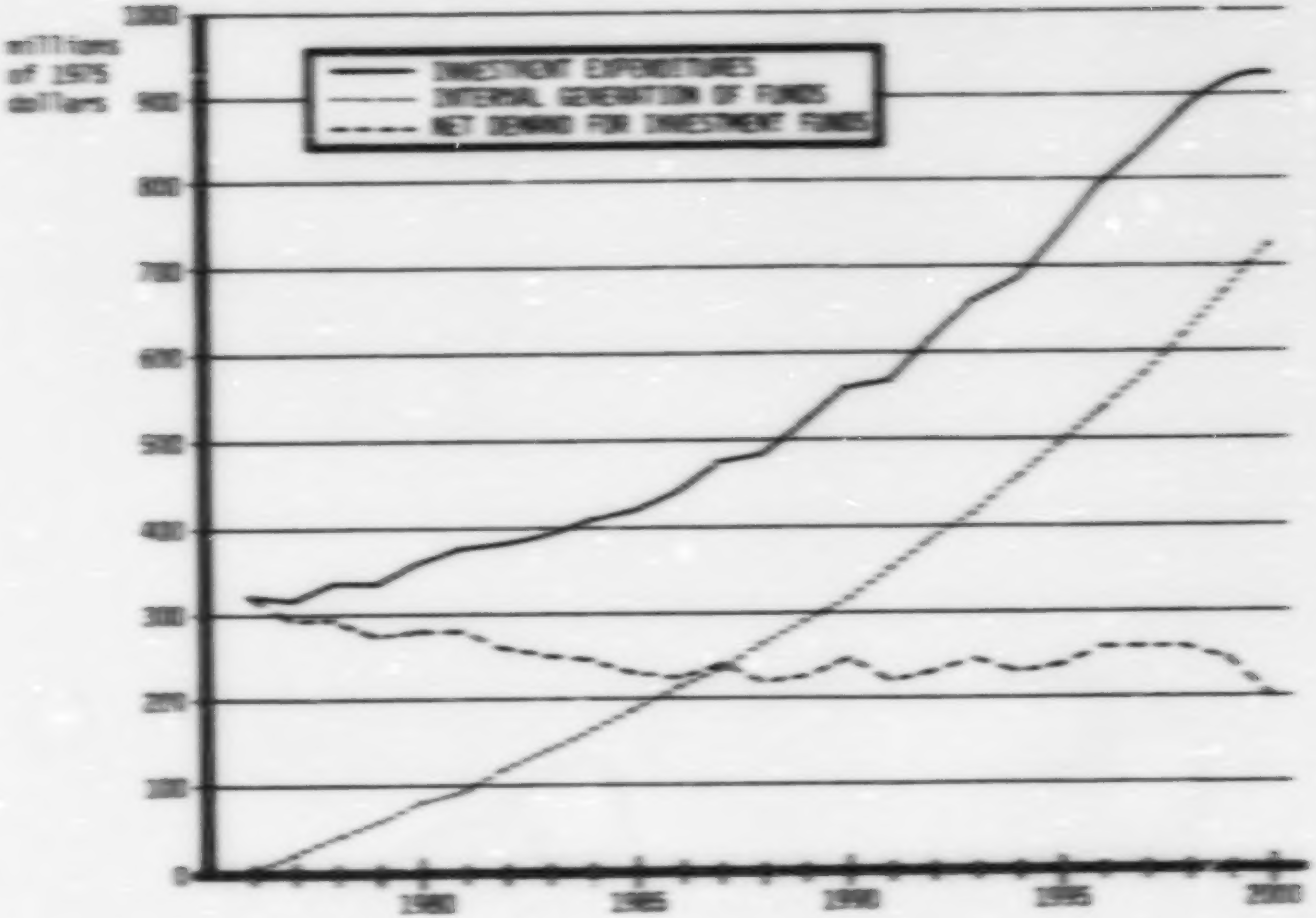

FIGURE 12-5: SURFACE COAL MINES, CASH FLOW, ANNUAL, ALL MINES OPENING 1976-2004

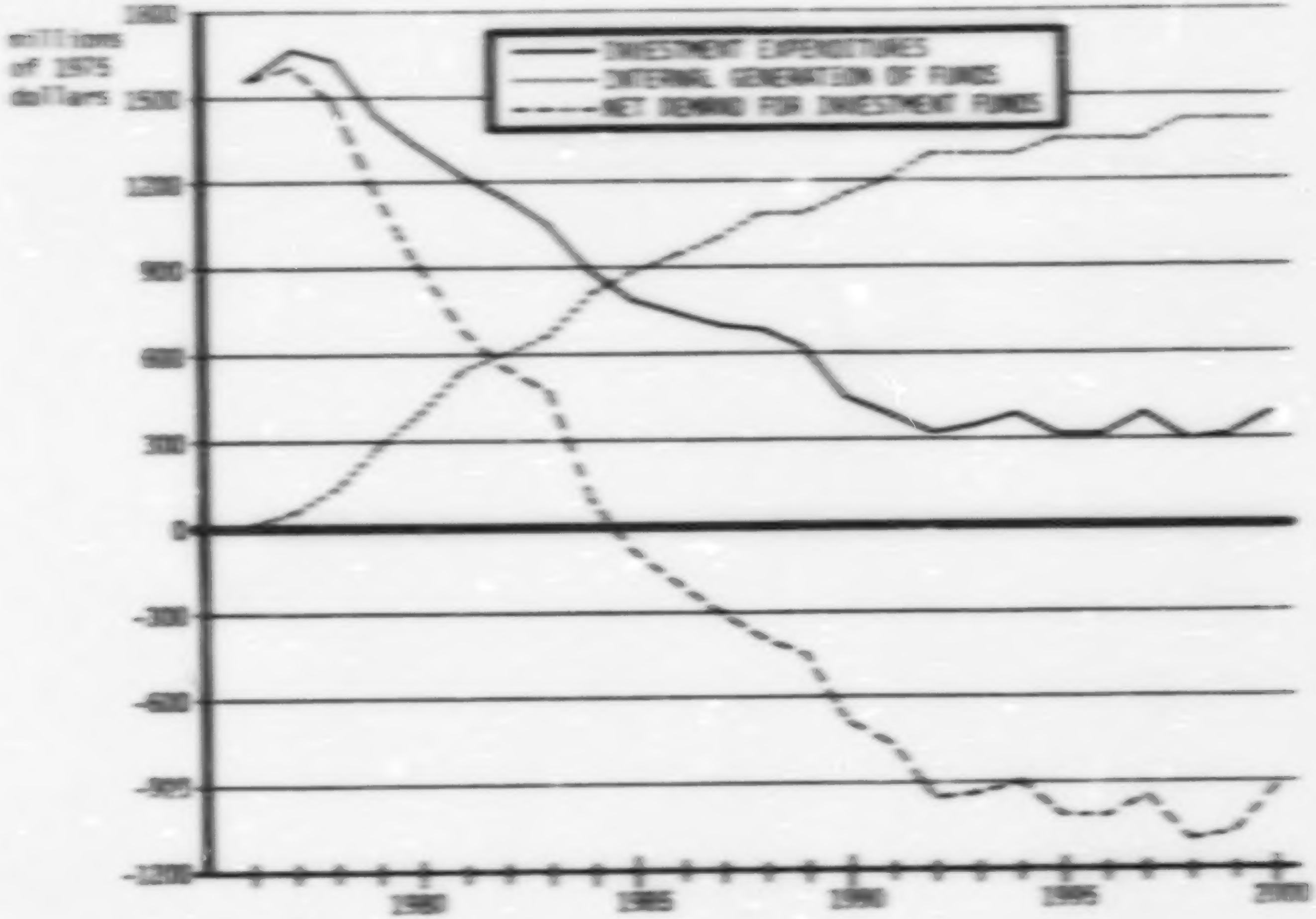

FIGURE 12-6: MINE-MOUTH POWER, CASH FLOW, ANNUAL, ALL PLANTS OPENING DURING 1976-2000

TABLE 12-53: CASH FLOW, 1976-2000, FIVE MAJOR ENERGY SYSTEMS IN WESTERN STATES
(billions of 1975 dollars)

Investment	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	Total
Gross Investment						
Oil Shale	0.36	2.42	4.69	10.52	24.13	42.12
Gasification		1.22	8.10	20.81	39.80	69.93
Surface Mining	1.67	1.98	2.48	3.27	4.35	13.75
Mine-Mouth Power	7.59	5.05	3.13	1.68	1.69	19.14
Transportation	5.15	5.62	7.01	9.59	13.69	41.06
Gross, Five Systems	14.77	16.29	25.41	45.87	83.66	185.99
Return Cash Flow	2.75	11.54	12.02	20.36	35.04	81.71
Net Investment	12.02	4.75	13.39	25.51	48.62	104.28

Source: Carasso, M., *et al*. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, *et al*. *A Western Regional Energy Development Study: Economics*, Final Report. 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

As shown in Figure 12-7, these diverse trends add up to a very stable $2 billion rate of investment for the first 8 years, not counting transportation. During that period mine-mouth power would take the major portion funds. By 1984, 36,000 MWe would be on-line. These facilities would contribute a return cash flow of almost $800 million per year, an amount equivalent to 37 percent of the requirements for all new construction. However, in the mid-1980's, fundamental changes would begin to occur. First oil shale and then gasification will "take-off". By 1989, gasification will be absorbing funds faster than the previous peak of mine-mouth power. Oil shale, though lagging during most of the time frame, will probably consume more funds between 2000 and 2010 than will gasification.

In short, energy development would require about $2 billion per year in new funds for quite a while, but after 1988 investment dwarfs anything previously encountered, reaching a $17 billion annual rate by the end of the century and still accelerating.

In terms of a regional disaggregation, the largest investments would be required in Montana and North Dakota before 1990 and in Colorado after 1990 (Table 12-54).[1] In Montana and North Dakota, investments would be needed primarily for mine-mouth power plants; in Colorado, they would be needed for oil shale development. Gasification would represent a sizable share of investment in the Northern Great Plains states after 1990. Table 12-54 also shows that the Low Nuclear case is a high investment case for the region because nuclear power would be replaced largely by western coal.

New transportation facilities would comprise an important link in the western energy system and would boost total investment costs of the four resource technologies by 28 percent or $41 billion (Table 12-53). This estimate is based on assumptions stated in Table 12-55 where the substantial costs of transporting coal, compared to the synthetic energy forms, can also be seen. In fact, that feature of synthetics is one of the prime incentives for adopting them. (Transportation costs and capacities are described further in Section 12.9.)

The other energy systems in the aggregated scenario have negligible capital requirements. For example, although each underground mine requires more capital than surface mine of similar size, surface mines will outnumber underground mines 296 to

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[1] This table differs from the previous tabulation in that only completed facilities are counted and interest costs are included. These alterations bring the results closer to figures that would be used in tax assessment.

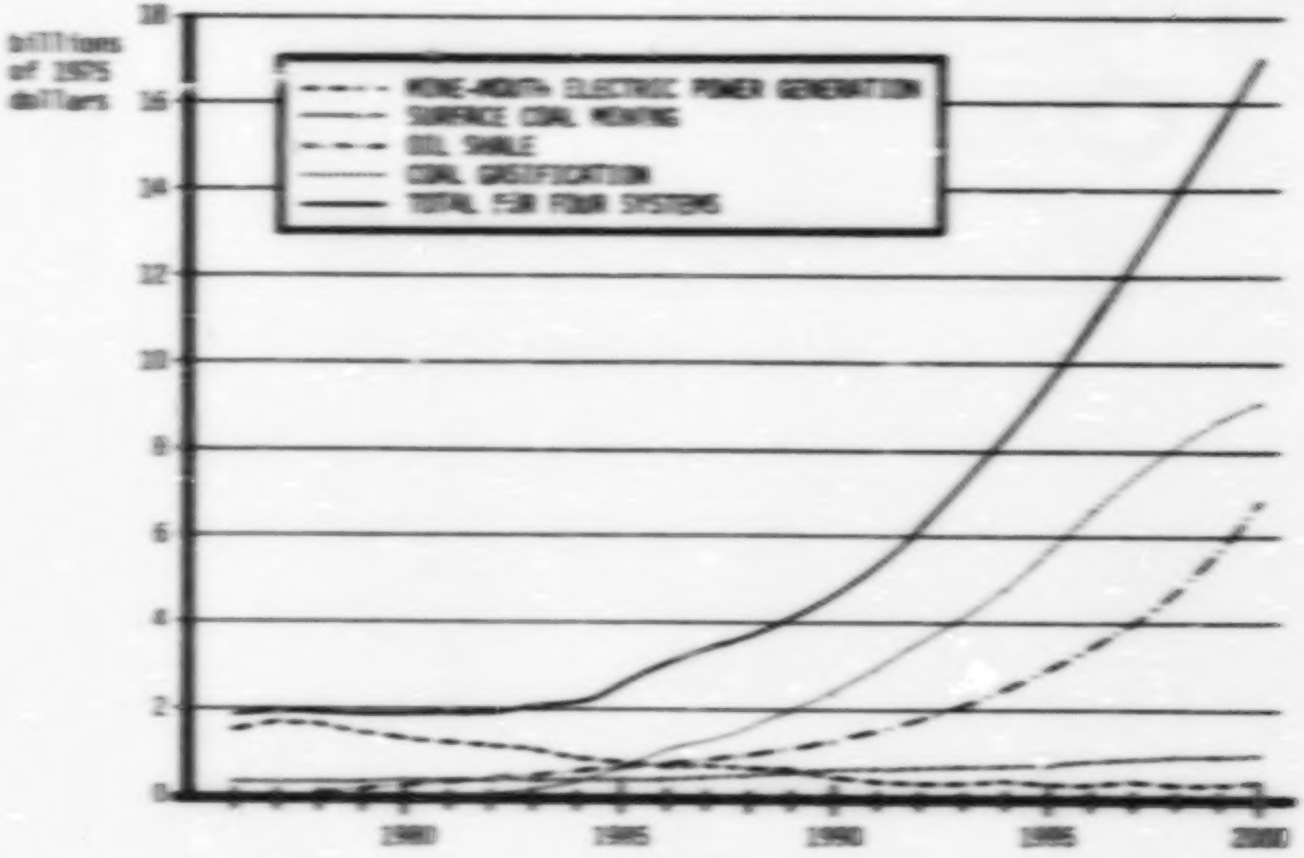

FIGURE 12-7: ANNUAL RATE OF INVESTMENT FOR WESTERN ENERGY SYSTEMS

TABLE 12-54: VALUES OF FACILITIES PLACED IN OPERATION, BY STATE, 1975-1990 and 1990-2000, UNDER THREE ENERGY SCENARIOS
(billions of 1975 dollars)[a]

State	1975-1990			1990-2000		
	Nominal	Low Demand	Low Nuclear	Nominal	Low Demand	Low Nuclear
Colorado	7.02	5.66	6.10	33.90	28.54	38.92
New Mexico	1.51	1.44	3.02	3.76	1.46	4.30
Utah	2.87	1.36	4.25	4.21	3.17	5.74
Montana	10.85	6.18	13.26	19.94	14.78	24.05
North Dakota	10.90	8.22	12.84	25.72	16.15	26.67
Wyoming	4.06	5.10	6.53	13.24	6.66	14.30
Total (Six States)	37.21	27.96	46.00	100.77	70.76	113.98

Source: Carasso, M., *et al.* *The Energy Supply Planning Model.* San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics,* Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[a] Four energy systems are considered: gasification, oil shale, mine mouth electricity, and coal mining. Figures include interest cost.

TABLE 12-55: INVESTMENT COSTS FOR ENERGY TRANSPORT, 1975-2000
(in 1975 dollars)

Transport Mode	Resource	[illegible]	[illegible]	[illegible]
Slurry pipeline	Coal	[illegible]	[illegible]	[illegible]
Unit train	Coal	[illegible]	[illegible]	[illegible]
Gas pipeline	Gas from coal	[illegible]	[illegible]	[illegible]
Extra-high voltage transmission	Electricity	[illegible]	[illegible]	[illegible]
Oil pipeline	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]		[illegible]

Btu = British thermal unit

Source: Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics,* Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[a] [illegible]

15 by 2000. As another example, uranium mining and milling have very low capital requirements per British thermal unit (Btu).

Nevertheless, the Nominal case estimates a western uranium output of 22.67Q's (10^{15} Btu's) per year by the end of the century, which would require substantial investment in both enrichment and reactor facilities. In fact, if all the uranium output went to light water reactor plants, an investment of some $190 billion would be required or an average of $6.9 billion per year beyond the nuclear capacity currently in place. Enrichment and other fuel processing facilities could require an additional $15 billion. These costs are noted in passing but are not among the prime concerns of this study because the facilities would be located outside the region.

Another category of costs not analyzed in detail is pollution control. Little hard information is available in this area. Nevertheless, electrical power plants will probably have to invest at least $100 per kilowatt (and perhaps twice that) for control of sulfur emissions.[1] (Control devices will also entail operating costs, use some of the plants' electrical output, and reduce thermal efficiencies. Other pollutants will require control devices, too, such as electrostatic precipitators for fly ash. The costs of sulfur control are considered here simply to indicate the orders of magnitude involved.) The $100 per kilowatt figure implies additional capital costs of $760 million during 1976-1980, $820 million in the 1980's and $340 million in the 1990's. Since the synthetic fuels systems are still being developed, it is difficult to estimate pollution control costs associated with them. The major problem area, as pointed out in Section 3.2, would seem to be that of fugitive hydrocarbons.

B. Impact on Capital Markets

The financial demands described above can be compared with the overall size of U.S. financial markets and the energy industries' historical share of those markets (Table 12-56). Equipment expenditures over the decade ending in 1975 averaged 7.90 percent of GNP.[2] An average of 7.8 percent up to 2000 and a

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[1] Ottmers, D.M., *et al.* *Evaluation of Regenerable Flue Gas Desulfurization Processes*, 2 vols. Austin, Tex.: Radian Corporation, 1976, Vol. 1, p. 20.

[2] As reported in the "New Plant and Equipment Expenditures" series in the *Survey of Current Business*; published monthly by the U.S., Department of Commerce.

TABLE 12-56: INVESTMENTS FOR WESTERN ENERGY COMPARED TO NATIONAL NEW PLANT INVESTMENTS
(in billions of 1975 dollars)

Time Period	Investment in Western Energy (Five Systems)[a]	New Plant, all Industries	Percentage
1976-1980	14.8	648	2.28
1981-1985	16.3	770	2.12
1986-1990	25.4	914	2.78
1991-1995	45.9	1,086	4.23
1996-2000	83.6	1,289	6.49
1976-2000	185.9	4,707	3.95

Source: Table 12-53 and assumptions in text.

[a] Oil shale, coal gasification, surface mining, mine-mouth power generation, and transportation.

compound GNP growth rate of 3.5 percent per year are assumed in the following comparisons. This is consistent with the 2.8-percent energy growth rate implicit in the SRI Nominal case.[1] The proposed investments would not severely strain national capacity to build industrial structures and durable equipment, at least from this highly aggregated perspective. Even during the projected gasification and oil shale development boom, western energy development will constitute no more than 7 percent of the nation's new plant and equipment.

The share of investment traditionally taken by the energy industries provides another yardstick. The U.S. Department of Commerce categories of electric and gas utilities, petroleum companies (domestic operations only), and mining companies together have usually accounted for approximately 30 percent of all new plant and equipment expenditures. In the last 5 years, these industries have been investing at a rate of $36 billion per year (1975 currency). Allowing a 3.5-percent annual growth rate, western energy projects would take the following proportions of the sector's investments:

	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	Average
Percent	7.4	6.9	9.0	13.7	21.1	12.8

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[1] Together, the two assumptions allow for gradual implementation of energy conservation; for the average industry, British thermal units per dollar output will decrease by 0.7 percent per year.

By the 1990's, western development will begin taking a noticeable share of energy investment, but it will be replacing other investments, such as conventional oil and gas drilling. Thus, the energy sector should maintain its historic share of investment activity, even as it shifts to new technological systems.

C. Capacity of Firms

Although western energy development is not large when compared either to the economy as a whole or to the energy industries, the projects envisioned in the scenarios could challenge the capacity of even the largest individual firms. The overall capital requirement would not be intolerably large, but the expenditures must be made in major segments.

At present, there are only three surface mines in the U.S. in the 6-million tons per year (MMtpy) range and only eight deep mines in the 2-MMtpy range.[1] When linking together modules into annual production units of 16 million tons (underground) and 12 million tons (surface), as our scenarios envision, the resources of any firm currently in the field would be challenged. In fact, only six firms produced more than 16 million tons in 1974. However, the coal industry has demonstrated a long-standing tendency toward larger units. Both mines and firms have recently increased substantially in size, especially during the 1960's. The average size of the top 50 mines grew from 1.92 MMtpy in 1957 to 2.90 MMtpy in 1974.[2] At the same time, the industry has been concentrated into fewer firms. Announced plans, especially in the West, feature some large operations, and large operations will probably lead to larger firms. One feature of this expansion might well be the conglomeration of the industry, only 3 of the top 15 producers are exclusively coal companies; the others are owned by diversified metals companies and petroleum companies.[3]

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[1] *1975 Keystone Coal Industry Manual*. New York, N.Y.: McGraw-Hill, 1975, p. 499.

[2] Pennsylvania State University, Institute for Research on Human Resources. *The Demand for and Supply of Manpower in the Bituminous Coal Industry for the Years 1985 and 2000*. Springfield, Va.: National Technical Information Service, 1973; *1975 Keystone Coal Manual*.

[3] One of these large companies, Kennecott Copper Company, was ordered to divest itself of its subsidiary, Peabody Coal, the nation's largest coal producer. The Federal Trade Commission had to approve the proposed sale.

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[2] Pennsylvania State University, Institute for Research on Human Resources. *The Demand for and Supply of Manpower in the Bituminous Coal Industry for the Years 1985 and 2000*. Springfield, Va.: National Technical Information Service, 1973; *1975 Keystone Coal Manual*.

[3] One of these large companies, Kennecott Copper Company, was ordered to divest itself of its subsidiary, Peabody Coal, the nation's largest coal producer. The Federal Trade Commission had to approve the proposed consortium by October 1, 1977.

Table 12-57 lists 20 firms representative of those having made or likely to make substantial commitments in western energy development, along with the value of their fixed assets. A single $1.2-billion facility would boost the assets of the median company by 67 percent in one step. Such investments would entail substantial risk and require outside financing.[1]

Judging from these factors, and from tendencies already appearing, western energy industries may develop along the following lines:

1. Outside sources of capital will be required, and diversified energy companies will develop coal resources. Such 'horizontal' expansion will not eliminate risks but will at least prevent their being positively correlated with the companies' other risks.[2]

2. As mines grow, so will mining firms. Independent coal companies will continue to form mergers or be acquired by oil companies (Consolidation Coal in Continental Oil, Island Creek Coal in Occidental Petroleum, etc.). Coal companies have also merged with metal mining companies.

3. Even these larger, diversified organizations will find it necessary to work in consortia. Four firms will each take a share of four projects, rather than each one having its own.

4. The new, large, diversified, project-sharing groups will still need outside capital. By traditional standards, investors will rely more on the soundness of the particular projects than on the developer's balance sheet. In this regard, "project financing" resembles a mortgage. However, banks are going beyond the risks of traditional industrial mortgages by allowing repayment to be conditioned on

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[1] Arnold, Bob. "New Outlook for Coal: Not So Sensational and Not So Troubled." Wall Street Journal, July 28, 1976.

[2] Negatively correlated risks "cancel out". Realization of this had led to an extensive literature on portfolio theory, beginning with Markowitz, H.M. Portfolio Selection. New York, N.Y.: Wiley, 1959.

TABLE 12-57: FIRMS REPRESENTATIVE OF THOSE ENGAGED IN WESTERN ENERGY DEVELOPMENT, AND THEIR FIXED ASSETS

Company	Assets (millions of dollars)[a]
Standard Oil Indiana	5,580
Shell Oil Company[b]	3,905
ARCO	3,769
Southern Pacific Company	3,062
Sun Oil Company	2,574
Union Pacific Corporation	2,403
Burlington Northern, Inc.	2,347
Santa Fe Industries	2,158
Phillips Petroleum	2,154
Texas Eastern Transmission	1,818
Standard Oil Ohio	1,747
El Paso Company	1,466
Pacific Power and Light	1,370
Northern Natural Gas	1,186
Public Service Colorado	1,123
Ashland Oil	791
Utah Power and Light	700
Kerr-McGee Corporation	651
Pacific Lighting	475[c]
Montana Power	372

Source: Moody's Investors Service

[a] Land, plant, and equipment net of depreciation, as of December 31, 1974.

[b] Majority owned by the international Royal Dutch group.

[c] Inferred; most assets held by subsidiaries, especially Southern California Gas.

> successful operation of the facility;[1] they usually rely on firm, long term sales contracts. In turn, the purchasing utilities want to assure themselves of timely delivery and so buy railroad rolling stock. In short, future developments will require close coordination of all the participants, and they will commit themselves on an *ad hoc* basis only after examination of detailed plans.

D. Market Risks

According to the SRI model, if oil prices continue to rise, synthetic fuels systems would become attractive investments without governmental subsidies by 1990. The Nominal case assumes that world oil prices will advance from the 1975 price of $11 per barrel to $16 per barrel by the end of the century (real prices). In such a case, interfuel competition, with each technology receiving its "minimum acceptable price", would drive imported oil out of the market. Shale syncrude, Lurgi gas, etc. could be produced for a total cost less than $16 per barrel equivalent according to SRI assumptions.

However, if the international oil cartel cannot (or will not) maintain prices, their oil will supply an increasingly large share of the U.S. energy market. SRI has run a sensitivity analysis in which world oil prices first fall, then rebound to $10 by the end of the century. In that case, oil shale development would be almost completely forestalled.

Investors are particularly wary of oil price changes because they depend greatly on "subjective", unstable factors, rather than on inexorable technical factors. Production costs for oil in the Persian Gulf and other major fields are generally believed to account for only a small fraction of the selling price. The high price is maintained through taxes, "artificial" restrictions of production, and collusive agreements, all of which are inherently unstable. If there was open competition in the world market, consumers everywhere could benefit greatly, but investors in expensive energy alternatives would lose essentially all monies put into such projects. Thus, investment in adequate amounts may not be forthcoming without some form of loan guarantee.

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[1] Wilson, Wallace W. "Capital for Coal Mine Development," Coal Mining and Processing, Vol. 13 (January 1976), pp. 68 ff.

12.4.11 Summary of Regional Social, Economic, and Political Impacts

As a result of energy developments likely for the western U.S. between the present and 2000, the study area population can be expected to increase by 768,000-1,248,000 people.[1] This population increase would generate most of the impacts discussed in this section. Predicted increases are modest for Colorado, New Mexico, and Utah, but they may be as great as 50 percent in Montana, North Dakota, and Wyoming. Increases as great as 600 percent through the year 2000 will occur in some local areas in the West.

As a result of the new employment in the energy industry, regional income can be expected to increase by nearly 30 percent (in constant dollars) by 2000. The relative importance of economic sectors will change as well, with significant shifts from agriculture to energy in the Northern Great Plains states. Consistent with these shifts, land use for energy facilities can be expected to vary between 11 and 19 percent of some counties in Montana, North Dakota, and Wyoming.

Local cultures and lifestyles will be affected, particularly those of ranchers, farmers, and Indians. Political preferences may also change as a result of the influx of new residents. However, quality of life impacts will depend mostly on local conditions, and especially on how local governments are able to respond to stresses induced by the new population. Their success will largely depend on their ability to plan and manage growth.

Inflation can be expected to occur in some localities because of increased demands and inadequate supply of goods and services.

Regional capital expenditures by governments for services will approach $200 million per year between 1990 and 2000. In the aggregate, tax revenues should be adequate to cover these expenditures. However, jurisdictional barriers may lead to problems when revenues accrue in a jurisdiction other than the one most severely impacted.

Equipment, capital, and personnel availability problems can also be expected to occur. Capital requirements for energy facilities will not, on the aggregate, be a large fraction of total capital required nationally for plants and equipment. However, the size of individual facilities will be so large that single companies are unlikely to have adequate capital. As a result, more joint ventures and outside financing will be required. On the whole, energy development would require about $2 billion per year in new funds for quite a while, but after 1988 investment would rapidly move to new levels, reaching a $17 billion annual rate by the end of the century and still accelerating.

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[1] The levels of energy development are taken from Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics*, Final Report, 2 Vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

Railroads and railroad equipment manufacturing industries would have to grow by about 15 percent by 1985 as compared to required growth without energy development. This would require investments of as much as $420 million annually. Foundries would realize a 10-percent increase in business to 1985 as well.

Regional impacts due to increased business from western energy development can be expected in cities such as Birmingham due to railroad equipment construction, Pittsburgh due to steel and railroad equipment, and Duluth-Superior due to iron mining.

Personnel resources will, for the most part, be adequate, but there will be substantial demands for chemical and mining engineers as well as a particularly high demand for boilermakers. All these demands must be met by establishing or enlarging training programs for these occupations.

12.5 ECOLOGICAL IMPACTS

12.5.1 Introduction

A diversity of plant and animal communities occur in the eight-state study area. Consequently, the stresses to ecosystems from energy development will vary by location depending on the biological communities present. The ecological impacts sections in Chapters 6-11 identify and describe the kinds of impacts that can be anticipated given various local conditions. Many of the consequences of regional scale development will be qualitatively similar to local scenarios; they will simply occur in more locations. Regional development can also pose cumulative stresses that will have ecological significance. Four of these stresses are discussed here: thr impacts of consumptive water use on aquatic habitats; the loss and degradation of terrestrial communities through large-scale changes in land-use patterns; the potential for reclaiming mined lands; and the emission of large quantities of sulfur dioxide (SO_2) into the atmosphere. These stresses may act independently and synergistically to produce changes in plant and animal populations in the study area.

This section identifies regional impacts on the area's biological communities and gives examples of the kinds of impacts that result from altering existing stresses which currently determine the abundance and distribution of plant and animal populations.[1]

Throughout the eight-state area, the man-made and natural factors that act as stresses to ecosystems and their component populations vary in different areas. Consequently, these ecosystems differ in both their ability to sustain new stresses without deterioration and their resiliency or ability to recover from the changes induced by new stresses. These locational differences are highlighted in the following discussion.

12.5.2 Impacts from Water Consumption

Of all the habitats found in the study area, aquatic habitat is by far the most limited in extent. Further reduction in this habitat will have more widespread effects to both aquatic and terrestrial species than changes to large areas of terrestrial habitat. Development of the water resources needed for the regional scenario will result in three principal changes to aquatic habitats: decreased stream flow, changes in water quality, and construction of water supply reservoirs.

A. Flow Reduction

As indicated in Chapters 6-11, stream-flow depletion arises from direct removal and consumption of water, aquifer depletion, and runoff control. Anticipated water demands from regional development for the Nominal case are included in section 12.3.[2] Because major withdrawals will commence between 1990 and 2000, demands for the Stanford Research Institute's Nominal case are greater for the year 2000. The total energy-related demand by 2000 would be well below the average discharge of many rivers in the region, but water demand would be equivalent to a large proportion of typical low flows and would equal or exceed the low flow of record.[1] However, the water required by energy developments would not all be withdrawn from existing low flows but, in part, would come from water released from storage in upstream reservoirs.[2]

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[1] For example, factors that often limit the size and well-being of animal populations are the amount and condition of the ecosystem types that are available. Because many species require different kinds of habitat, the loss of only a small part of a population's total range may have a disproportionately large effect. Riparian (stream-side) habitat may be especially important for food gathering or water supply to some species. Other species may require lower elevation habitat for winter forage. These habitats may be a small portion of either the total range or habitat available, but they are critical to maintaining a population.

[2] The extent of this problem depends on how the demands for water are divided between rivers and how reservoirs are used to regulate flow.

The greatest impacts on aquatic ecosystems could occur in the San Juan Basin and western Colorado. Increased irrigation such as the Navajo Indian Irrigation Project, will consume additional water and add significant amounts of nutrient-, pesticide-, and silt-laden runoff to the San Juan; flow depletion could seriously reduce the dilution capacity of the river. Together, these factors may alter the extent and quality of the aquatic habitat in the San Juan River and in the San Juan arm of Lake Powell.

In western Colorado, heavy water demands could deplete flows in the White, Green, and Colorado Rivers. Even if as little as a quarter of the total water requirement for the area is apportioned to the White, demand would exceed typical minimum daily flows. The Colorado, measured near Rifle, commonly experiences minimum daily flows which will fall short of the total demand projected for the year 2000. Problems arising from excessive demand could be mitigated by using water from the Green River, although this river also experiences low minimum flows. Severe flow depletion could reduce aquatic habitat and the ability to sustain threatened or endangered species.[3]

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[1] The physical impact of flow reduction will be most noticeable in the summer and late winter months when flow is normally at its lowest. Depending on the ultimate distribution and use of water rights, water withdrawals could reduce discharge in some rivers to zero or nearly zero. Zero flow does not necessarily mean that there is no water in a stream bed but merely that it is not moving and therefore does not constitute a flow.

[2] In most parts of the eight-state region, large main-stem reservoirs on the Colorado and Missouri Rivers afford a source of stored water both for industrial use and maintenance of base flow. In other locations, new reservoirs would be needed to sustain flow during periods of low snowmelt and limited rainfall.

[3] A number of techniques for determining in-stream flow needs for biological resources have been reviewed. One simplified generalization suggests that flows be maintained at 25-30 percent of the average daily flow as much as 55 percent of the time. However, such measures tend to be quite unreliable when applied to specific situations. Bovee, K.D. The Determination, Assessment, and Design of "In-Stream Value" Studies for the Northern Great Plains Region. Denver, Colo.: Northern Great Plains Resources Program, 1975.

The Yellowstone River and its tributaries could experience withdrawals from 25 to 100 percent of typical low flows, depending on the use of reservoirs to regulate discharge. The portion of the Yellowstone from Billings, Montana to the Missouri confluence is free-flowing, and there is considerable public pressure to keep it so. However, the river is 20-100 miles from many of the coal deposits and thus a long-distance delivery system typically involving reservoirs would be required. Irrigation demands on the Yellowstone are already high and could increase, further reducing dilution capacity and increasing nutrient and pesticide concentrations brought in by agricultural runoff. Expanded crop production, even on non-irrigated acreage, will add to the pollutant load entering the river through runoff.

The two main-stem rivers in the study area will reflect the cumulative influence of upstream and tributary withdrawals. As discussed in Section 12.2.1, the water required from the Upper Colorado amounts to 32-52 percent of the unused water in the river.[1] However, marshlands in the lower valley could very likely be affected both in extent and species composition.[2] Section 12.3.2 indicates that cumulative flow reduction in the Lower Missouri River Basin could curtail navigation roughly 1 in 3 years and that in 11 of 75 years no navigation may be possible. This great a reduction in flow, although not quantified as a proportion of present low flows, would undoubtedly produce serious adverse effects on the aquatic ecosystem.

In addition to affecting the aquatic community directly, reduced river flow will exert an influence on terrestrial vegetation if floodplain water tables are lowered due to insufficient recharge from the stream. Riparian and floodplain habitats are perhaps the most important individual habitat types in the Great Plains and southwestern deserts. They are used at least seasonally by many upland species as wintering habitat or hunting range, as well as supporting a distinctive and diverse animal community. They are among the most limited in extent of the major habitat types throughout the eight-state region and are rapidly being fragmented by urban and agricultural expansion. Riparian marshes important to waterfowl would be narrowed in some areas and perhaps lost, although in others, shoaling and reduced current velocity could induce a cycle of sedimentation and growth of emergent plants.

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[1] The degree to which flow in the Lower Colorado may be reduced by this demand depends on the extent of actual use of presently allocated water and on use of reservoir discharge to maintain base flows.

[2] Loss of these habitats could prove critical to the officially "threatened" Yuma clapper rail, as well as the black rail and a large number of waterfowl and shorebirds that find other suitable wetlands habitat scarce in the area.

B. Water Quality Changes

Water consumption in the upper parts of the main river basins of the study area will reduce both volume and dilution potential downstream. Added to the impact of the effect of evaporation on this reduced volume will further increase salinity, particularly in the Lower Colorado River Basin (LCRB). Without salinity control, salinity levels may increase to 1,100-1,400 milligrams per liter (mg/ℓ).[1] With more successful operation of the Colorado salinity control projects, salinities at or above Imperial dam should range between 730-1,000 mg/ℓ.[2] A number of researchers have found that freshwater fish can generally live in water with total dissolved solids (TDS) as high as 7,000 mg/ℓ, and some salt-tolerant freshwater species are found in natural waters with concentrations as high as 20,000 mg/ℓ. On the basis of a broad literature survey, some state agencies apply a 2,000 mg/ℓ limit as a water quality criterion for maintenance of freshwater fish and aquatic life.[3]

The salinities expected to develop in the LCRB appear too low to cause redistribution or mortality in fishes. However, there is very little evidence to use in evaluating the possibility of subacute impacts either on fish or on other aspects of the aquatic ecosystem. The impact of in-flowing pollutants from leaching mine spoils, agricultural runoff, irrigation return flows, and municipal sewage treatment effluent will add stresses.

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[1] U.S., Environmental Protection Agency, Regions VIII and IX. *The Mineral Quality Problem in the Colorado River Basin*, Summary Report and Appendices. Denver, Colo.: Environmental Protection Agency, 1971; Colorado River Board of California. *Need for Controlling Salinity of the Colorado River*. Sacramento, Calif.: State of California, 1970; and U.S., Department of the Interior, Bureau of Reclamation, Office of Saline Water. *Colorado River International Salinity Control Project*, Special Report. Bureau of Reclamation, 1973.

[2] Maletic, J.T. "Salinity Control Planning in the Colorado River System," in Flack, J.E., and C.W. Howe, eds. *Salinity in Water Resources: Proceedings of the 15th Annual Western Resource Conference*, University of Colorado, July 1973. Boulder, Colo.: Merriam Publishing, 1974.

[3] McKee, Jack Edward, and Harold W. Wolf. *Water Quality Criteria*, 2nd ed. Sacramento, Calif.: Resources Agency of California, State Water Quality Control Board, 1963.

C. Reservoir Construction

Additional impoundments will be required in the study area to insure a reliable source of water for energy development. For example, in the Yellowstone River Basin new impoundments would be needed to insure supply during late summer, fall, and winter.[1]

The reservoirs needed for energy developments are a very different kind of habitat than the original river. Impoundments reduce turbidity, trap sediment, and stabilize chemical variations. A large reservoir stratifies seasonally into a warm, productive upper layer and a colder lower layer in which the dissolved oxygen content may be lowered. Non-game fish may be able to compete with game fish more successfully, or game fish may simply lose much of their suitable spawning areas (as happened recently in North Dakota's Lake Sakakawea).

Some reservoirs can develop highly productive, diverse ecosystems if they combine good water quality with a variety of habitats, especially shoreline spawning and nursery areas. If reservoirs experience large water-level fluctuations to maintain flow to energy facilities, then shoreline habitat cannot be maintained. Generally, reservoirs also have in-flows contaminated by pollutants and sediments. The reservoir sites most vulnerable to this pollution would be on major rivers in the Great Plains.[2] Mountain reservoirs would generally be less likely to become eutrophic.

To date, most of the large impoundments in the study area have been on main-stem rivers. However, concern about protecting the remaining free-flowing river habitats, as well as the cost of building large dams, may induce a trend toward off-stream impoundments. By trapping sediment and releasing steady flows of cool water, they could improve both the baseline quality of the remaining aquatic habitat and the stream's ability to assimilate municipal wastes.

In general, reservoirs increase the supply of some species, such as sport fish, both within the impoundment and frequently below it. However, the overall diversity of species may be reduced in areas where warm-water fishes predominate, although the quality of the sport fishery may improve. Aquatic habitat will also be fragmented by reservoir construction, which will introduce effective barriers to movement of biota upstream and downstream. Finally, reservoir construction and operation will eliminate valuable floodplain vegetation or lower its productivity.[1] Thus, reservoirs will have a mixture of effects that will increase the abundance of some species and stress or eliminate populations of others.

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[1] Montana, Department of Natural Resources and Conservation, Water Resources Division. *Which Way? The Future of Yellowstone Water*, Draft. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1976, pp. 25-34.

[2] Most of the lakes and large impoundments in North Dakota have become highly eutrophic from nutrients and sediment brought in by agricultural runoff.

12.5.3 Terrestrial Habitat Degradation by Changing Land Use

As stated in the site-specific impact analyses in Chapters 6-11, the greatest stress to terrestrial ecosystems usually stems from the loss or degradation of habitat. Direct consumption of land for energy facilities can have an adverse influence either if the amount of land required is large, as in western North Dakota lignite fields, or if it overlaps areas of critical importance to animals, such as migratory routes or breeding areas. When both industrial and urban land disturbance is scattered through a vegetational type, the resulting fragmentation compounds the effects. A relatively small amount of the total plant community is eliminated but leaves no large areas without some degree of disturbance, and thus reduces the value of the remaining habitat. Finally, people exert a disturbing influence that typically thins out animals wary of human settlements.[2] We have concluded that the three major causes of habitat deterioration are: urban and residential expansion, dispersed recreation in wilderness and backcountry area, and changes in land use from mining and reclamation. The first two factors are discussed below, and the third factor is covered in Section 12.5.4.

A. Urban and Residential Expansion

The most critical factor related to the effect of urban expansion is the pattern in which development occurs. Scattered trailer parks, subdivisions, and individual dwellings built on small parcels of land (e.g., less than 5 acres) usually exert a much larger overall affect on habitat than similar area use around a few urban foci. Factors that contribute to these residential patterns are discussed in Chapter 14.

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[1] Johnson, W.C., R.L. Burgess, and W.R. Keammerer, "Forest Overstory Vegetation and Environment on the Missouri River Floodplain in North Dakota," Ecological Monographs, Vol. 46 (Winter 1976), pp. 59-84.

[2] For example, as indicated in Chapters 6-11, outdoor recreational activities, particularly use of snowmobiles and other off-road vehicles, brings this disturbance into backcountry areas that have not been previously disturbed. Disturbances in winter can be important to some animals due to additional metabolic demands during periods of high physiological stress.

Predicted population growth and land needs are described in Section 12.4. The areas most affected are the Powder River coal region, the Western Colorado, the lignite fields of Western North Dakota, and the Four Corners area.

Within these areas, certain habitats are likely to be more vulnerable than others to fragmentation and disturbance due to residential expansion. Especially in western Colorado and Utah, rough terrain often limits buildable sites to river and stream valleys, habitats which are both limited in extent and important to maintaining overall ecological diversity. The growing demand for recreational second homes in scenic mountain areas will also put pressure on foothill habitats, which are more buildable and accessible than higher elevations.[1] This kind of land use may be expected to develop particularly in the southern foothills of the Rockies bordering the desert of the Colorado Plateau,[2] in western Colorado's oil shale areas, and the Black Hills. The biological implications of the development in foothill winter ranges may be greater for some species than others. For example, these areas are typically the limiting factor controlling big game herds in these areas.[3]

B. Impacts of Increased Outdoor Recreational Pressure

Regional ecological stresses brought on by energy development are closely related to the size of human populations in the study area. (Anticipated growth in regional human populations is detailed in Section 12.4.3.) As shown in Table 12-58, the cumulative percent increase of population projected over the entire eight-state region will be more than 10 percent by 1990, and a disproportionate share of this growth will occur near areas with high value for backcountry recreation. As a new energy impact, the baseline against which this growth in resident demand should be measured is the projected growth in tourists (nonresidents). Estimates made for the Upper Colorado River Basin and Missouri River Basin Comprehensive Framework Studies indicate

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[1] For example, these patterns of land development are described in: Montana State University, Gallatin Canyon Study Team. The Gallatin Area: A Summary Report, Bulletin 344. Bozeman, Mont.: Montana State University, Cooperative Extension Service, 1974, pp. 9-13.

[2] Including the deserts of southern Utah across the Navajo Reservation to central northern New Mexico.

[3] For example, these patterns of land development are described in: Gallatin Canyon Study Team. Gallatin Area, pp. 20-21

TABLE 12-58: EXPECTED POPULATION INCREASES DUE TO NOMINAL CASE DEVELOPMENT IN SELECTED STATES AND THE EIGHT-STATE REGION[a]

Year	Colorado	New Mexico	Wyoming	Total Eight-State Region
1975	2,534,000	1,147,000	374,000	9,551,000
1980	2,000	31,800	23,000	95,500
1990	42,600	28,700	46,900	280,900
2000	375,800	68,100	204,300	1,247,600

[a] See Section 12.4 and Table 12-34 for additional details.

that it is reasonable to expect this demand to double or triple by the year 2000. Since the early 1970's, backcountry activities such as hiking, snowmobiling, jeeping, and backpacking or packing with horses have been rising in popularity, accounting for 5-15 percent of the total use in individual national forests.

Residents and non-residents generally have different backcountry use patterns. Residents are more often responsible for off-road vehicle use, including snowmobiles. Backpacking, hiking and camping may be more evenly divided, while ski developments generally draw recreationists from long distances.[1]

Although the intensity of use is uncertain, the locations of recreational activities generally fall into three categories: major established tourist attractions (e.g., Yellowstone and Grand Teton National Parks); areas near population centers (e.g., Grand Mesa National Forest, near Grand Junction); and recreational areas with otherwise limited recreational opportunities (e.g., Black Hills National Forest in Wyoming and South Dakota). Table 12-59 lists some major areas which are likely to experience increased use because of regionwide energy development. If access to these areas is limited or controlled, the bulk of the growing demand will fall on adjacent non-designated areas which still have a strong aesthetic appeal.

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[1] An important limitation in projecting recreational demands is the difficulty of anticipating trends in recreational styles. For example, such technological innovations as snowmobiling are recent phenomena. Hydrofoil and shallow-draft boats make many western rivers available for recreational use. Similar uncertainty exists in land management practices. Current trends are to increase restrictions on wilderness and backcountry areas, but economics encourages the Forest Service to promote dispersed recreational activities by building trails and improving access.

TABLE 12-59: MAJOR BACK-COUNTRY AREAS LIKELY TO RECEIVE INCREASED PRESSURE DUE TO ENERGY DEVELOPMENT[a]

State	National Forests, Parks and Monuments	Included Wilderness And Primitive Areas
Colorado	Grand Mesa N.F. Rio Grande N.F.	La Garita W.A.; Upper Rio Grande P.A.
	Routt N.F.	Rawah W.A.; Mt. Zirkel W.A.
	White River N.F.	Maroon Bells/Snowmass W.A.; Gore Range/Eagle's Nest W.A.; Flat Tops W.A.
	San Juan N.F. Black Canyon of the Gunnison N.M. Mesa Verde N.P. Theodore Roosevelt N.P.	San Juan W.A.
New Mexico	Carson N.F. Santa Fe N.F. Chaco Canyon N.M.	Wheeler Peak W.A. San Pedro Parks W.A.
South Dakota	Black Hills N.F.	
Utah	Ashley N.F. Dixie N.F. Fishlake N.F. Arches N.P. Dinosaur N.M. Zion N.P. Glen Canyon R.A. Cedar Breaks N.M. Capitol Reef N.P. Canyonlands N.P. Bryce Canyon N.P. Hovenweep N.M.	High Uintas P.A.
Wyoming	Bighorn N.F. Bridger-Teton N.F.	Cloud Peak P.A. Teton W.A.; Bridger W.A.
	Medicine Bow N.F. Shoshone N.F.	North Absaroka W.A.; Popo Agie P.A.; Washakie W.A.; Glacier P.A.
	Yellowstone N.P. Grand Teton N.P. Bighorn Canyon R.A. Flaming Gorge R.A.	

[a] N.F. = National Forest
N.M. = National Monument
N.P. = National Park
P.A. = Primitive Area
R.A. = Recreation Area
W.A. = Wilderness Area

Energy-related population growth will probably result in potential damage to vegetation, and animal communities in four areas: western Colorado, the Powder River coal region, the Four Corners area, and the lignite fields of western North Dakota. In western Colorado, the large population influx is expected to locate in the midst of prime outdoor recreation areas; consequently, this area is likely to experience the greatest adverse ecological impacts. The Powder River and North Dakota areas will also experience substantial population increases; however, in these areas, outdoor recreationists will be limited in their choice of wilderness or backcountry areas. The three closest such areas (the Theodore Roosevelt National Memorial Park, the Black Hills National Forest, and the Bighorn National Forest) will receive concentrated use. The Custer National Forest, with few developed trails, campgrounds, or other facilities, may remain comparatively unused. The energy-related population growth in Utah and New Mexico (Four Corners) is expected to be comparatively small. Thus, although high quality wilderness and backcountry areas surround the area, these areas should not experience significant usage increases resulting from regional energy development. Some local impacts will occur, as discussed in Chapter 6 and 7.

12.5.4 Surface Mining and Reclamation

The impact of surface mining depends on the extent of mining, the reclamation practices employed, the existing conditions of soil and climate, and the objectives of the reclamation activity. Important variables of reclamation practice are practices in separation of topsoil and subsoil from the overburden, adjustments of topography, mulching, seeding, fertilization, and irrigation. The variety of existing conditions ranges from the rich soils of the Northern Great Plains with their low to moderate rainfall to the poor soils and arid climate of the desert southwest. The objectives of reclamation can vary from restoring natural conditions to establishing range grasses, providing of cover and forage for wildlife, and production of crops. Restoration of mined lands for productive use have also included proposals for commercial or recreational activities such as lakes, golf courses, or race tracks in locations near urban areas.[1] This section primarily addresses the process of reclamation for the establishment of biological resources, which can include native species, game animals, or croplands. Following a discussion of the extent of mining as projected by the regional scenario for the eight-state study area, this section identifies some of the major factors that affect reclamation, and describes the potential for success and the problems in reestablishing vegetation. A review of selected issues and alternatives for dealing with reclamation problems is provided in Section 14.3.

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[1] For examples of economically successful projects, see: Ozarks Regional Commission. *Mined-Land Redevelopment: Kansas, Missouri, Oklahoma*. Wichita, Kans.: Wichita State University, 1973, p. 6-8.

Since the early 1970's, a great deal of laboratory and field research has been performed to determine whether, and by what means, mine spoils can be reclaimed in the major western coal fields. Some critics express uncertainty about the soundness of long-range predictions based on the results of these short-term tests. Their reservations largely arise because of the inevitable lack of data concerning the long term success of reclamation.

The total acreage ultimately disturbed by surface mining under the three demand cases postulated for the eight-state scenario is summarized by sub-area in Table 12-60. These sub-areas reflect both the geographic distribution of major coal resource areas and natural groupings of biotic communities. The Northern Great Plains includes the coals of eastern Montana and northern Wyoming and North Dakota's lignite, all part of the Fort Union Formation; the Intermountain sub-area includes coal deposits in Utah, western Colorado and western Wyoming; and the Southwest Deserts include the coals of northern New Mexico and adjacent Arizona. It is possible to generalize about the conditions that influence the success of reclamation in these three major sub-areas within the eight-state study area, as summarized below.

A. Existing Conditions Affecting Success of Reclamation

The climate, soils, and overburden characteristics are the most important locational factors determining the success of reclamation. Precipitation is an important component of climate. As indicated in the following section, approximately 6-10 inches of precipitation are generally considered to be the lower limit for successful revegetation, although the frequency and timing of this precipitation may be more important than the total amount.[1]

Surface soils within the eight-state study area vary greatly in sand content, organic content, and depth, and a single mine often contains several soil types which differ in their suitability for use in reclamation. Thus, the following general observations are regional trends rather than uniformly occurring conditions. Rock strata overlaying coal deposits (overburden) also vary greatly. However, throughout the three sub-areas, certain characteristics typify the major geological formations where coal is found.

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[1] Grant Davis, U.S., Department of Agriculture, Forest Service Seam Program, Personal Communication, November 3, 1976.

TABLE 12-60: SURFACE ACREAGE ULTIMATELY DISTURBED BY MINING

	Low Demand Case	Nominal Case	Low Nuclear Availability Case
Northern Great Plains North Dakota Lignite[a] Powder River[b]	 446,700 acres 395,700	 480,000 581,600	 560,000 813,400
Intermountain[c]	39,900	47,600	79,400
Southwest Desert[d]	68,900	121,900	179,000

[a] Includes Billings, Bowman, Dunn, Hettinger, McKenzie, McLean, Mercer, Oliver, Slope, Stark, and Williams Counties. Assumed average seam thickness of 12.5 feet.

[b] Includes Powder River, Bighorn and Rosebud Counties, Montana, assumed average seam thickness 27 feet; and Campbell, Johnson, and Sheridan Counties, Wyoming, assumed average seam thickness 64 feet.

[c] Includes Rio Blanco, Garfield and Huerfano Counties, assuming 1/3 of the projected mines are underground, and an average seam thickness of 7 feet.

[d] Includes San Juan County, New Mexico, with an assumed average seam thickness of 10.3 feet; and Kane and Garfield Counties, Utah, assuming half the projected mines are underground, and an average seam thickness of 10 feet.

1. Northern Great Plains

Most precipitation in the Northern Great Plains falls in spring and summer showers[1] and averages between 12 and 16 inches annually on most coal lands in the area. The timing of this rainfall is offset somewhat by the drying effects of the prevailing northwesterly winds,[1] especially in the western part of this sub-area. As much as 20 percent of the rain that falls during the growing season may evaporate without penetrating to plant roots.[2] In addition, the climate is erratic,[3] and while the overall climate favors revegetation, periods of lowered moisture will reduce the success of seedlings or alter the composition of vegetation.

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[1] Cook, C.W., R.M. Hyde, and P.L. Sims. *Guidelines for Revegetation and Stabilization of Surface Mined Areas in the States.* Range Science Series No. 16. Fort Collins, Colo.: Colorado State University, Range Science Department, 1974.

Soils in the area generally have adequate nutrient and organic matter content to support plant growth. Topsoils may be 6-10 inches in depth, and weathered subsoil extends as deep as 20 feet in western North Dakota.[4] Topsoil varies with topography, and soils on steep slopes erode so that deep soils do not develop. Soils on level terrain are much deeper.

High salt content is a problem in some Northern Great Plains soils.[5] These soils are poorly drained, minimally permeable and dry to a hard crust. Runoff from such soils is high, and they tend to erode. Soils in Wyoming and Montana tend to be deficient in phosphorus, while North Dakota soils may have insufficient nitrogen.[1]

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[1] Packer, Paul E. *Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains*, General Technical Report INT-14. Odgen, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974; and Wali, M.K., and F.M. Sandoval. "Regional Site Factors and Revegetation Studies in Western North Dakota," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[2] Curry, R.R. "Biogeochemical Limitations on Western Reclamation," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[3] Thornthwaite, C.W. "Climate and Settlement on the Great Plains," in U.S., Department of Agriculture. *Yearbook of Agriculture*. Washington, D.C.: Government Printing Office, 1941.

[4] Wali and Sandoval. "Regional Site Factors and Revegetation."

[5] Sandoval, F.M., *et al.* "Lignite Mine Spoils in the Northern Great Plains: Characteristics and Potential for Reclamation." Paper presented before the Research and Applied Technology Symposium on Mined Land Reclamation. Pittsburgh, Pa.: Bituminous Coal Research, 1973; and Packer, Paul E. *Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains*, General Technical Report INT-14. Odgen, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

Material below the soil and above the coal (overburden) in the Fort Union Formation is typically high enough in sodium to limit or prevent plant growth.[2] Overburden above lignite is more likely to present sodium problems than is the overburden overlying the subbituminous coal of the Fort Union Formation.[3] These spoils are also susceptible to erosion, especially under the relatively high rainfall of North Dakota. Overburden generally contains low or marginally adequate amounts of mineral nutrients; plant cover almost always responds to nitrogen and phosphorus fertilizers.[4] Potassium is sometimes adequate,[5] but calcium may be needed.[6]

2. Intermountain Sub-area

The varied topography and climate of the Intermountain subarea are the major determinants of the distribution of the three major vegetation types found over coal lands: foothill shrubland, pinyon-juniper woodland, and mountain shrub communities. The foothill shrublands generally receive from 9 to more than 15 inches of rainfall annually. Most precipitation falls as snow, with erratic showers of rain in spring and early summer. July and August tend to be dry, and native plants are often dormant during this period. Year-to-year variation is wide, and in drought years only 6-7 inches of rainfall may occur.[1] Pinyon-juniper woodlands at 4,000-7,000 feet receive 12-15 inches of rainfall annually.[2] Mountain shrub communities above this zone receive 15-30 inches of rainfall each year, about half of it as snow. Generally, precipitation is more favorable to revegetation at these altitudes than at other elevations in the Intermountain region.

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[1] Packer, Paul E. *Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains*, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[2] Sandoval, F.M., *et al.* "Lignite Mine Spoils in the Northern Great Plains: Characteristics and Potential for Reclamation." Paper presented before the Research and Applied Technology Symposium on Mined Land Reclamation. Pittsburgh, Pa.: Bituminous Coal Research, 1973.

[3] Packer. *Rehabilitation of Surface-Mined Land*.

[4] Meyn, R.L., J. Holechek, and E. Sundberg. "Short and Long Term Fertilizer Requirements for Reclamation of Mine Spoils at Colstrip, Montana," pp. 266-79 in Clark, W.F., ed. *Proceedings of the Fort Union Coal Field Symposium*, Vol. 3: *Reclamation Section*. Billings, Mont.: Eastern Montana College, 1975; and Power, J.F., *et al.* "Factors Restricting Revegetation of Strip-Mine Spoils," pp. 336-46, in Clark, W.F., ed. *Proceedings of the Fort Union Coal Field Symposium*, Vol. 3: Reclamation Section. Billings, Mont.: Eastern Montana College, 1975.

[5] Sindelar, B.W., R.L. Hodder, and M. Majerus. *Surface Mined Reclamation Research in Montana*, Research Report No. 40. Bozeman, Mont.: Montana Agricultural Experiment Station, 1972.

[6] Power, *et al.* "Factors Restricting Revegetation."

Soils in the Intermountain sub-area vary greatly, having developed over a wide variety of original rock. Three major types are found in the coal-producing regions.[3] Soils of dry sagebrush plateaus, mesas, and foothills in Utah are generally loamy but poor in organic matter and range from 20 to 60 inches in depth. Soils of sagebrush and juniper canyonlands, lower mountain slopes, and barren areas are less than 20 inches deep and subject to water erosion. Soils on western Colorado coal lands are loamy, rich in organic matter, and contain a variety of vegetation types; subsoils may contain clay and may have permeability problems. These soils are typically deep and are often farmed for dryland crops. All three of these soil types may require irrigation.

Because of the area's variable geology, generalizations about overburden characteristics cannot be made. For example, in western Colorado, mine spoils from the Mesa Verde formation are predominately fragmented hard rock and have low water holding capacity compared to finer materials. Therefore, vegetation is difficult to establish and maintain. These spoils are low in both available phosphorus and nitrogen needed for plant growth.[1]

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[1] National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974.

[2] Plummer, A.P., D.R. Christensen, and S.B. Hansen. Restoring Big Game Range in Utah, Publication No. 68-3. Salt Lake City, Utah: Utah, Department of Natural Resources, Division of Fish and Game, 1968; and Water Resources Council, Upper Colorado Region State-Federal Inter-Agency Group. Upper Colorado Region Comprehensive Framework Study. Denver, Colo.: Water Resources Council, 1971.

[3] Upper Colorado Region State-Federal Inter-Agency Group. Comprehensive Framework Study.

Although part of the Mesa Verde formation, overburden in the western Wyoming Kemmerer coal fields varies considerably. Acid-producing iron pyrite is present in some strata, while others are alkaline. The salinity, ease of erosion, high aluminum content, and low pH (acidity/alkalinity) of some overburden materials make plant growth difficult. The overburden in this area generally contains enough mineral nutrients to accommodate the growth of plants in a greenhouse, although additional nitrogen helps.[2]

3. Southwestern Deserts

Precipitation in this area is usually insufficient for satisfactory revegetation of mine spoils without supplemental irrigation. Annual rainfall averages 5-8 inches, but in exceptional years may range from 3 to 12 inches.[3] Rain falls largely in late summer (July through September); spring and fall seasons are generally dry.[4] Rainfall is often very irregular,[5] and conditions favorable for seeding and establishing plants may occur naturally only 1 in 10 years.[6] The timing of rainfall is particularly critical; experimental work with one native grass on wild lands in New Mexico showed that it could be planted with 80-percent success during only 2 weeks in the year; success fell rapidly to zero both before and after this period.[1] In areas such as Arizona's Black Mesa, high, gusty winds occur throughout the year. This enhances evaporation and thus results in inadequate soil moisture, even though rainfall may reach 12 inches annually.[2]

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[1] Berg, W.A. "Revegetation of Land Disturbed by Surface Mining in Colorado," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[2] Lang, R.L. "Reclamation of Strip Mine Spoil Banks in Wyoming." *University of Wyoming Agricultural Experiment Station Research Journal*, Vol. 51 (1971).

[3] National Academy of Sciences. *Rehabilitation Potential of Western Coal Lands*, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974.

[4] Aldon, E.F., and H.W. Springfield. "Problems and Techniques in Revegetating Coal Mine Spoils in New Mexico," in Wali, M.D., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[5] Gould, W.L., D. Rai, and P.L. Wierenga. "Problems in Reclamation of Coal Mine Spoils in New Mexico," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[6] Aldon and Springfield. "Revegetating Coal Mine Spoils."

Soils in the arid coal regions of Arizona and New Mexico are generally poorly developed, hold little moisture, and are high in salt content. Moreover, these soils are often sandy and the loss of vegetation through overgrazing leads to erosion. Drifting and blowing soils can easily bury seedlings or reduce plant cover by abrasion.[3]

Mine spoils in the southwest may also pose problems. For example, in the Fruitland Formation in the San Juan Basin, the sandstones and shales generally contain excessive amounts of sodium, low quantities of phosphorus, and variable amounts of nitrogen.[4] The development of soil-based mineral cycling systems takes place slowly. Centuries might be required before vegetation stabilizes,[1] and 10-30 years may be required for natural revegetation.[2]

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[1] Aldon, E.F. "Establishing Alkali Sacaton on Harsh Sites in the Southwest," *Journal of Range Management*, Vol. 28 (March 1975), pp. 129-92.

[2] Thames, J.L., and T.R. Verma. "Coal Mine Reclamation in the Black Mesa and the Four Corners Areas of Northeastern Arizona," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[3] National Academy of Sciences. *Rehabilitation Potential of Western Coal Lands*, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974; Thames and Verma. "Coal Mine Reclamation."; Gould, W.L., D. Rai, and P.J. Wierenga. "Problems in Reclamation of Coal Mine Spoils in New Mexico," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975; and Aldon, E.F., and H.W. Springfield. "Problems and Techniques in Revegetating Coal Mine Spoils in New Mexico," in Wali, M.K., ed. *Practices and Problems of Land Reclamation in Western North America*. Grand Forks, N.D.: University of North Dakota Press, 1975.

[4] Gould, Rai, and Wierenga. "Problems in Reclamation."

B. Probable Success of Revegetation

The success of a reclamation effort and the techniques needed to achieve it are very much influenced by the objectives of a reclamation program and local features. The differences in soil and overburden characteristics described above may require slightly different treatments between areas within a single mine, and soils and underlying strata can vary markedly in their suitability for reclamation within a few miles.[3] However, it is difficult to predict the success of revegetation in many western locations on the basis of available experimental results and field observations. As indicated above, local climatic conditions and the unreliability of rainfall over most of the area can potentially make the difference between success and failure in revegetation efforts. Further, in most areas, current experience covers a period of 6 years or less, which is not sufficient for the long-term stability of revegetated areas to be assessed.[4]

Reclamation efforts in the western U.S. will be limited most consistently by the timing and quantity of moisture available to plants.[5] The amount of precipitation and its seasonal distribution largely determine the likelihood of successful revegetation, even though soils vary in their ability to retain the amount that falls in a manner which makes it available to plants.

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[1] National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation, Cambridge, Mass.: Ballinger, 1974.

[2] Cook, C.W., R.M. Hyde, and P.L. Sims. Guidelines for Revegetation and Stabilization of Surface Mined Areas in the Western States, Range Science Series No. 16. Fort Collins, Colo.: Colorado State University, Range Science Department, 1974.

[3] For example, soils of poor texture and low organic content can be improved by mulching. Soils of low nutrient content can be fertilized with nitrogen, phosphorus, or other limiting elements.

[4] Farmer, E.E., et al. Revegetation Research on the Decker Coal Mine in Southeastern Montana, Research Paper INT-162. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[5] See for example: NAS. Rehabilitation Potential of Western Coal Lands; Cook, Hyde, and Sims. Revegetation and Stabilization; Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

As indicated in the previous descriptions, areas generally receiving an average of 10 or more inches of rainfall per year can be made to support some plant growth without supplemental irrigation.[1] When mined lands have been graded with care and planted properly with suitable species, some areas with as little as 6 inches of rain have been revegetated.[2] In most of the semi-arid West, however, rainfall varies widely from year to year. Under these circumstances, periodic dry years or droughts lasting several years must be expected, and the success of revegetation at such times will be curtailed, especially in marginal areas.[3] The timing of rainfall is crucial to the establishment of plant cover. A lack of precipitation shortly after planting can reduce seedling success, and a difference of only 1-2 inches over the entire growing season may have significant consequences depending on its timing. Because of this, there will be a significant number of cases where reclamation efforts will either fail or be only marginally successful, especially where poor soil or top-soil characteristics are combined with an arid climate. Erratic rainfall patterns over the lifetime of a given mine may also be expected in years when seedling failure is unavoidable.

Over the long term, it will probably be possible to establish a cover of range grasses capable of containing erosion on most sites in the Northern Great Plains and in the higher foot-hill coal fields receiving adequate rainfall. However, this long-term trend may be punctuated by setbacks from periods of drought, and provision for irrigation would mitigate this. During these periods, intensive management will be required for both seeded and established vegetation. Revegetation of some of the drier foothill sites will have a lesser chance for success, depending primarily on stresses over and above those arising from climate (such as those resulting from soil salinity and provisions for irrigation). Finally, in view of experience and the many adverse influences arrayed against desert sites, revegetation will be difficult unless the sites are prepared carefully and seedlings are planted, intensively managed, and irrigated, with grazing and public access strictly controlled.

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[1] National Academy of Sciences. *Rehabilitation Potential of Western Coal Lands*, a report to the Energy Policy Project of the Ford Foundation, Cambridge, Mass.: Ballinger, 1974.

[2] Grant Davis, U.S., Department of Agriculture, Forest Service SEAM Program. Personal Communications, November 3, 1976.

[3] NAS. *Rehabilitation Potential of Western Coal Lands*. Packer, Paul E. *Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains*, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

C. Reclamation for Specific Biological Objectives

Four biological objectives for reclamation are restoring natural vegetation, providing wildlife habitat, establishing livestock forage, and establishing croplands. Re-establishing native vegetation is difficult, and in some instances the original vegetation has not been present for decades or longer. Reclamation for wildlife is a more complicated process than restoration for livestock forage or cropland use. In contrast to grazing or farming, wildlife restoration must meet the needs of a relatively large number of animal species, which in turn requires a greater variety of plant species. Site characteristics, such as diverse topography and exposure, also play a large part in determining both the variety of vegetation that becomes established and the value of the habitat to wildlife.[1]

In addition to topographical variability, wildlife diversity and abundance are related to the spatial patterning of vegetation. A mosaic of grasses, low shrubs and thickets, and taller trees, combined with available free water, are necessary for many western species such as sharptail and sage grouse, jackrabbits and cottontails, and many birds of prey. A combination of nutritive food plants adequate to meet the varied needs of grazers, browsers, and seed and fruit eaters is necessary to re-establish the full complement of native fauna, including insects that are important food sources.

Several factors limit the success of woody plants. First, these plants grow slower than grasses and forbs. To speed the process, nursery stock may be planted, but this is expensive. Second, once planted, young shrubs and trees need protection from wildlife and livestock for 10-15 years before they can tolerate browsing. Third, natural rainfall may be insufficient or competition from other plants for the limited moisture on mine spoils may inhibit success.

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[1] One example of the beneficial effects of diverse topography on wildlife values is the Knife River Coal Company's Beulah mine, which has helped maintain or increase the area's populations of grouse, pheasant, deer, and other small vertebrates. Prior to the establishment of state requirements for grading to a gently rolling contour, the spoils were left standing with only the ridgetops flattened. Planted shrub, grass, and forb species, selected for their food and cover value, have established thick stands in the valleys between the close-set spoil ridges where runoff provides high soil moisture content. Wildlife finds both food and shelter from winter storms, which typically cause large losses of upland wildlife. Western states now require mined lands to be regraded to some extent.

Reclamation may attempt to restore grazing alone. In the Northern Great Plains, particularly North Dakota, mined land may be planted to crops. This would favor animal species characteristic of early grassland succession rather than woody vegetation.[1] Intermountain cool areas are less homogenous, and thus it is more difficult to specify what changes in wildlife communities may take place. Unless shrubby cover is restored on foothill areas, however, deer and elk will be unable to use mined lands for winter range, and many western slope coals now underlie present big game winter ranges. As discussed in Chapter 7, strip mine areas in the desert southwest have already experienced stress from overgrazing, with an attendant loss of soil that will make restoration of rangelands more difficult. Also, even if successfully restored, these lands will likely be of low productivity.

Croplands may also be established in reclaimed areas and will likely expand in the eight-state region. The growth of agriculture may occur in the same time frame as the energy development scenario. A recent study[2] reports that new cropland is currently added at a nationwide rate of 1.25 million acres per year. At this rate, some 31 million acres will be brought under cultivation by the year 2000. However, a rapidly growing world food demand may result in the acceleration of agricultural expansion. Presently, only 81 percent (380 million acres) of the arable land in the U.S. is cropped. Thus, a theoretical maximum of 90 million acres could be added by 2000, not counting marginal lands requiring drainage or irrigation.[1] By comparison, land-use estimates for new energy facilities presented in this section for potential reclamation total only 1.7 million acres by the end of the century, much of which may ultimately be used for crops.[2]

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[1] In these "replacement" or successional communities in the Northern Great Plains, antelope, deer, grouse, jackrabbits, and a variety of small vertebrates will be infrequent on mined lands restored for grazing. Burrowing animals will be limited by the texture of the spoils themselves; black-footed ferrets and burrowing owls, normally associated closely with prairie dog colonies will also be affected.

[2] Pimental, D., et al. "Land Degradation: Effects on Food and Energy Resources." Science, Vol. 194 (October 8, 1976), pp. 149-55.

12.5.5 Ecological Impacts of Sulfur Pollution

A great deal of concern exists concerning the potential damage of widespread SO_2 emissions on vegetation in the western energy resource states.[3] For example, livestock grazing is a major economic activity, and the potential threat of energy development to rangeland productivity can become a major issue in the eight-state area. Forests and other vegetation are also regarded as important resources. In view of projected increases in livestock grazing of up to 80 percent by the year 2000,[4] even small, chronic declines in productivity over large areas of the West could have measurable economic impacts.

The impacts of SO_2 emissions, both directly and through the formation of sulfates, including acid rain, have received much attention, and adverse effects on vegetation have been widely documented. However, two major knowledge gaps prevent investigators from using regional SO_2 emission figures to predict the possibility of chronic SO_2 damage or acid rainfall; insufficient knowledge of the mechanisms by which SO_2 emissions may be translated into particulate sulfate fallout rates or low rainfall pH, and inadequate sophistication of dispersion models at a regional level.[1]

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[1] In addition to new cropland being brought under cultivation, existing cropland is currently being lost at a national rate of 2.5 million acres per year to highways and urbanization. Since 1935, 100 million acres have been lost because of soil erosion. Most of these represent lost native ecosystems and wildlife habitat (although farms abandoned due to erosion eventually regain their value as habitat, at least for successional species). Thus, between 1975 and 2000 the nation may lose between 93 and 152 million acres of rangeland and native ecosystems from activities other than energy development, and reclamation for agricultural purposes may have a high priority according to agricultural interests.

[2] Highest land demands occur in the Northern Great Plains where reclamation for cropland is most feasible.

[3] Gordon, C.C., and P.C. Tourangeau. "Biological Effects of Coal-Fired Power Plants," in Clark, W.F., ed. *Proceedings of the Fort Union Coal Field Symposium, Vol. 5. Terrestrial Ecosystems Section.* Billings, Mont.: Eastern Montana College, 1975, pp. 509-30.

[4] Northern Great Plains Resources Program. *Effects of Coal Development in the Northern Great Plains: A Review of Major Issues and Consequences at Different Rates of Development.* Denver, Colo.: Northern Great Plains Resources Program, 1975.

According to the air impact analysis in Section 12.2, SO_2 emissions in Montana and North Dakota could exceed 3 million tons per year (tpy) in 2000 if scrubbers are not used, and would reach 700,000 tpy in North Dakota and 1,400,000 tpy in Montana with scrubbers. Impacts in the oil shale development region, especially in Rio Blanco County, Colorado, are further complicated by the irregularity of the surrounding terrain, which can permit pollutants to be trapped in low-lying areas or cause plumes to impact on prominent ridges or mountainsides. Although it is not possible to make definitive statements about the likelihood of either particulate sulfate fallout or acid rain in these areas, the question may be approached by analogy with experiments or case histories as described below.

The effects of air pollution on the structure and function of plant communities can be separated into three classes:[2] undetectable or potentially beneficial effects; chronic harmful effects; and acute harmful effects.[3] Undetectable or potentially beneficial impacts are associated with low pollution loads. Although there may be no detectable impact on individual plants, pollutants enter the mineral cycle of the ecosystem via normal pathways. This effect may not be harmful and may improve productivity if a particular mineral (such as sulfur) is in short supply.

Chronic effects arise from intermediate pollution loads that result in damage to susceptible plant species, such as pines, typically over periods of months or a few years. Such effects may include lowered productivity, reduced reproduction, or increased susceptibility to disease or insect infestation. Where species are affected differently, competitive relationships may be altered and the composition of species in a community changed. Acid rain can be placed in this category. In addition to its direct impacts on plants, acid rain is believed to cause increased leaching of nutrients from soils. The net effect on the entire plant community may be to reduce biomass and productivity.[1] This loss of mineral nutrients may be reversible only after very long periods of time, if at all.

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[1] Ground-level concentrations used in this section are derived from dispersion models which may have an error range of up to 50 percent. However, conservative assumptions built into the models are thought to result in predicted levels high enough to compensate for this error. The net result is a figure which may exceed, but probably does not underestimate, actual field conditions.

[2] Smith, W.H. "Air Pollution--Effects on the Structure and Function of the Temperate Forest Ecosystem." Environmental Pollution, Vol. 6 (February 1974), pp. 111-29.

[3] The term "harmful" effects here refers to reduction in plant growth or productivity.

Acute impacts occur when ambient pollutant concentrations are high enough to cause acute damage to plants. If sufficiently severe, this impact can eliminate species from the affected community. Since woody plants are often more susceptible to acute damage than are herbaceous species, loss of dominants may change the physical structure of the vegetation. Extensive vegetation loss results in erosion and affects mineral cycling through direct soil loss. In most ecosystems, these effects will combine to reduce the amount of primary plant production available to the animal community; further ecosystem simplification can take place as a result of reduced energy flow through the food web.

Acute and chronic impacts lessen the economic value of the vegetation and reduce its complexity and, perhaps, its ability to respond adaptively to other stresses such as drought. Low-level impacts may actually increase productivity in some circumstances. The following discussion covers acute impacts first, followed by chronic and low-level effects.

A. Acute Impacts

Leaf injury (damage) from short-term exposure generally requires very high levels of SO_2. Concentrations of SO_2 which experimentally produce acute damage in 2-7 hours for a number of common western range grasses, important wildlife browse plants, trees, and crops are tabulated in Table 12-61; these experiments indicate that damage occurs between 0.4 and 10 parts per million (ppm). Results were selected to show the effects of exposures corresponding roughly to the shortest averaging times (3-hour and 24-hour averages) used to calculated maximum ground-level SO_2 concentrations for the six development scenarios. Peak values for the site-specific scenarios are described in Section 12.2. Extreme high values, resulting from plume impaction on high terrain,

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[1] However, ecosystem impacts may not be simply additive because changed competitive relationships can bring about the dominance of new species able to tolerate pollution stress better than competitors.

TABLE 12-61: SELECTED SULFUR DIOXIDE CONCENTRATIONS WHICH EXPERIMENTALLY PRODUCED ACUTE INJURY IN WESTERN PLANT SPECIES

Species	Sulfur Dioxide Concentration	Duration	Type of Observation Conditions
Grasses			
W. Wheatgrass[a]	1.0-1.5 ppm	4 hours	Laboratory, greenhouse-grown plants
Crested Wheatgrass[b]	8 ppm	2 hours	Field fumigation
Needle-and-Thread grass[a]	1- 1.5 ppm	4 hours	Laboratory, greenhouse-grown plants
Blue Grama[b]	8 ppm	2 hours	Field fumigation
Galleta[b]	10 ppm	2 hours	Field fumigation
Indian ricegrass[b]	0.5 ppm	2 hours	Field fumigation
Shrubs			
Big Sage[b]	2 ppm	2 hours	Field fumigation
Rubber Rabbitbrush[b]	2 ppm	2 hours	Field fumigation
Mormon Tea[b]	4 ppm	2 hours	Field fumigation
Snowberry[b]	1 ppm	2 hours	Field fumigation
Curl-leaf mountain mahogany[b]	4 ppm	2 hours	Field fumigation
Gambel Oak[b]	10 ppm	2 hours	Field fumigation
Fringed sagewort[a]	1 ppm	4 hours	Laboratory, greenhouse-grown plants
Trees			
Subalpine fir[b]	10 ppm	2 hours	Field fumigation
Utah juniper and Rock Mtn. juniper[b]	10 ppm	2 hours	Field fumigation
Pinyon[b]	8 ppm	2 hours	Field fumigation
Ponderosa pine	10 ppm	2 hours	Field fumigation[b]
	0.5 ppm	7 hours	Laboratory transplanted stock[c]
	1 ppm	6-7 hours	Laboratory transplanted stock[c]
	0.38 ppm	6.2 hours	Laboratory[c]
Crops			
Alfalfa	0.5 ppm	4 hours	Laboratory[d]
	0.5 ppm	4-8 hours	Field and greenhouse fumigation[c]
	0.4 ppm	7 hours	Laboratory, greenhouse-grown plants[e]
Winter Wheat	2 ppm	2 hours	Field fumigation[b]
	1.15 ppm	1-3 hours	Laboratory; greenhouse plants[e]

[a] Tingey, D.T., R.W. Field, and L. Bard. "Physiological Responses of Vegetation to Coal-Fired Power Plant Emissions," in Lewis, R.A., N.R. Glass, and A.S. Lefohn, eds. The Bioenvironmental Impact of a Coal-Fired Power Plant. 2d Interim Report: Colstrip, Montana. EPA 600/3-76-013. Corvallis, Oreg.: Corvallis Environmental Research Laboratory, 1976.

[b] Hill, A.C., et al. "Sensitivity of Native Desert Vegetation to SO_2 and to SO_2 and NO_2 Combined." Journal of the Air Pollution Control Association, Vol. 24 (February 1974), pp. 153-157.

[c] Altman, Philip L., and Dorothy S. Dittmer, eds. Biology Data Book, 2nd ed. Bethesda, Md.: Federation of American Societies for Experimental Biology, 1973, Vol. 2.

[d] Tingey, D.T., et al. "Foliar Injury Responses of Eleven Plant Species to Ozone/Sulfur Dioxide Mixtures." Atmospheric Environment, Vol. 7 (February 1973), pp. 201-208.

[e] Zimmerman, P.W. In Proceedings of the United States Technical Conference on Air Pollution, Washington, D.C., 1950. New York, N.Y.: McGraw-Hill, 1952, p. 127.

may be as much as 0.8 ppm,[1] while in the ventilated areas with flat terrain and lower sulfur coal highest 3-hour maxima are down to 0.13 ppm.[2] Power plants, Synthoil plants, and TOSCO II (the Oil Shale Company) plants create the highest 3-hour average concentrations. These maxima approach concentrations that have produced experimental injury in ponderosa pine and alfalfa. More typical 3-hour periods produce ground-level concentrations one-tenth to one-hundredth as high.

However, large areas of vegetation would not be expected to experience acute toxicity under the worst dispersion conditions considered. High ground-level concentrations result from direct impaction of a plume on high terrain. The highest modeled 3-hour concentration, 0.76 ppm from the 100,000 barrels per day TOSCO II plant at Rifle, occurs under these circumstances. Here, concentrations remain consistently high throughout the averaging period, but the affected area is quite small (roughly 1 or 2 square miles).

For most scenarios, ground-level concentrations will be 3-10 times lower than concentrations known to cause acute injury in fumigation experiments. In some scenarios, however, irregular terrain may result in infrequent plume impaction that could raise ground concentrations to levels which may cause acute damage to sensitive species. Some visible damage to ponderosa pine could occur within limited areas, especially in southern Utah and western Colorado. Elsewhere, sensitive species may be exposed to SO_2 levels near, but below, known damage levels. Evergreens are susceptible year-round, but the worst dispersion conditions over most of the eight-state region occur in the winter when most vegetation species are in a seasonal minimum of activity.

B. Chronic Impacts

Chronic damage to plants typically occurs at much lower concentrations than does acute damage. The premature loss of needles observed near the Mount Storm power plant in West Virginia[3] was associated with average SO_2 concentrations of 0.01 ppm, although 1-hour maxima as high as 0.36 ppm were recorded. Reductions of 15 percent in the yield weights of grain have been reported for winter wheat under chronic SO_2 levels averaging

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[1] For the Rifle scenario, see Chapter 8.

[2] For the Gillette scenario, see Chapter 9.

[3] U.S., Environmental Protection Agency, Air Pollution Control Office. *Mount Storm, West Virginia/Gorman, Maryland and Luke, Maryland/Kaiser, West Virginia: Air Pollution Abatement Activity*, APTD-0656. Research Triangle Park, N.C.: Environmental Protection Agency, 1971.

0.015-0.05 ppm.[1] Chronic damage to alfalfa has been observed at concentrations between 0.024 and 0.051 ppm.[2] All these species are especially sensitive to SO_2.

Analysis of air impacts in the site-specific scenarios showed that multiple plume interactions seldom occur, and when they do, their cumulative effect on ground-level concentrations is less than the peak levels modeled for the individual plants. Consequently, in this regional discussion where the exact locations of the emission sources are not known, it is assumed that maximum ground-level concentrations can still be estimated in terms of individual plants, with the understanding that these impacts may be felt in many locations in the region as a whole.[3]

Using 24-hour averaging times, worst-case concentrations range between 0.003 ppm (Lurgi plant, Beulah) and 0.06 ppm (Power Plant, Rifle).[4] Assuming the cut-off point for chronic damage is 0.01 ppm, an examination of the peak 24-hour averages predicted for the local scenarios shows that concentrations exceeding this level can generally be expected downwind of power plants, at least at some time. However, these are infrequent peaks and cover much shorter periods than those usually associated with observed chronic SO_2 damage to plants in the field. Most of the time, 24-hour averages will be one-tenth or less of these peaks, which puts them below the harmful levels cited here. Thus, occasional 24-hour periods will probably occur when sensitive plants such as alfalfa are exposed to levels of SO_2 which could cause chronic damage.

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[1] Guderian, R., and H. Stratmann. *Forschungsberichte des Landes Nordrhein-Westfalen No. 1118*. Köln: Westdeutscher Verlag, 1968, p. 5; and Guderian, R., and H. Stratmann. *Forschungsberichte des Landes Nordrhein-Westfalen No. 1920*. Köln: Westdeutscher Verlag, 1968, p. 3.

[2] Guderian, R., and H. Van Haut. "Detection of SO_2 Effects Upon Plants." *Staub-Reinhaltung der Luft*, Vol. 30 (1970), pp. 22-35.

[3] Background SO_2 data are scarce in the western states. However, existing figures indicate that typical levels are only a few $\mu g/m^3$, too small to make a difference significant to plants when added to calculated ground-level concentrations arising from energy facilities.

[4] Peak 24-hour averages for the Escalante power plant are 0.09 ppm and are due to plume impaction; more typical peaks are 0.002 ppm.

Ecological damage thought to result from acid rainfall includes the widespread lowering of rainfall pH in Scandinavia from long-distance transport of sulfates from England and from Germany's industrialized Ruhr district.[1] In New Hampshire, rainfall acidification due to emissions from the urban-industrial complexes of New England has also been documented.[2] From these and other studies, the following points emerge:

1. *Mechanisms of Acidification*. The mechanisms by which rainfall is acidified are just now beginning to be understood qualitatively, and quantitative predictions of the effects on rainfall pH of given SO_2 emissions cannot yet be made. While some investigators have concluded that rainfall pH is governed by strong acids (such as sulfuric acid), others have presented evidence that weak acids may also be involved.[3] In spite of this lack of agreement, it is apparent that other ions besides sulfates are involved in determining the pH of rain. The major species appear to be sulfates, nitrates, and chlorides.[4] In addition to industrial sources, large amounts of nitrogen apparently enter the atmosphere because of the use of ammonia and nitrate fertilizers.[5] Atmospheric chloride ions, contributing to the formation of hydrochloric acid, originate from the sea.

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[1] Bolin, B., Chairman. *Sweden's Case Study Contributions to the United Nations Conference on the Human Environment--Air Pollution Across International Boundaries: The Impact on the Environment of Sulfur in Air and Precipitation*. Stockholm: Royal Ministry for Foreign Affairs, Kungl. Boktryckeriet, P.A. Norstedt et Soner, 1971.

[2] Whittaker, R.H., *et al.* "The Hubbard Brook Ecosystem Study: Forest Biomass and Production." *Ecological Monographs*, Vol. 44 (Spring 1974), pp. 233-54.

[3] Frohliger, J.O., and R. Kane. "Precipitation: Its Acidic Nature." *Science*, Vol. 189 (August, 8, 1975), pp. 455-57.

[4] Likens, G.E., and F.H. Bormann. "Acid Rain: A Serious Regional Environmental Problem." *Science*, Vol. 184 (June 14, 1974), pp. 1176-79.

[5] Tabatabai, M.A., and J.M. Laflen. "Nutrient Content of Precipitation Over Iowa," abstract in *First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts*. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

2. *Pathways into Terrestrial Ecosystems*. Much of the sulfur reaching Sweden has been shown to be in the form of neutral ammonium sulfate compounds. These particles, which are thought to form catalytically or photochemically in the air, enter the ecosystem as dry fallout. However, when the ammonia is absorbed by plants, both the remaining ammonia and the released sulfate ions tend to acidify soils.[1] Forest vegetation tends to filter out such particulates.[2] This may expose forests differentially to acidification problems. However, airborne alkaline or calcareous dust may increase the pH of rainfall and thereby counteract the effect of acid-forming substances in the air.[3] It has been suggested that the pH of rainfall depends jointly on atmospheric sulfur loading, the amount of dense forest vegetation in the area, and the extent of calcareous or limestone soils.[4]

3. *Geographic Variation*. Observations of chronic damage from acid rainfall are not always consistent geographically. Recent efforts to use tree-ring data to document the impacts of region-wide reductions in rainfall pH in New England and Tennessee failed to reveal a statistically

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[1] Dochinger, L.S., and T.A. Seliga. "Acid Precipitation and the Forest Ecosystem: A Report from the First International Symposium on Acid Precipitation and the Forest Ecosystem." *Journal of the Air Pollution Control Association*, Vol. 25 (November 1975), pp. 1103-5. Brosset, C. "The Role of Acid Particles in Acidification," abstract in *First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts*. Columbus, Ohio: Ohio State University, Atmospheric Sciences Programs, 1975.

[2] Davis, B.L., *et al*. *The Black Hills as a "Green Area" Sink for Atmospheric Pollutants*, First Annual Report, prepared for the USDA Rocky Mountain Forest and Range Experiment Station, Report 75-8. Rapid City, S.D.: South Dakota School of Mines and Technology, Institute of Atmospheric Sciences, 1975.

[3] Cooper, H.B.H., *et al*. "Chemical Composition Affecting the Formation of Acid Precipitation," abstract in *First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts*. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

[4] Winkler, E.M. "Natural Dust and Acid Rain," an abstract in *First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts*. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

> significant trend on a regional level, despite the evidence of the Hubbard Brook Study in New Hampshire.[1] Similarly, using the same method, no consistent trend in forest productivity has been discovered in Norway.[2] In the northeastern U.S., a recent investigation found that the rate of nutrient loss from upland forest watersheds is still quite low, in spite of the rising acidity of rainfall.[3]

Acid rain has also been associated with single large sources, including large power generation complexes. In studies of the effects of multiple-plant generation complexes in West Virginia and Tennessee, premature pine needle drop, damage to crops, and reduced soil fertility were correlated with acid rain. In these cases, SO_2 emissions were generally greater than individual plant projections in this technology assessment.[4] SO_2 emissions densities at levels projected for the Nominal case for the Powder River Region in the Year 2000 (see Section 12.2) are about one-third the SO_x emissions densities of the highest industrialized states (e.g., Ohio) in the East, assuming 80-percent SO_2 removal from power plants. However, in eastern locations, rainfall is four to six times greater than in the eight-state study area. Acid rainfall due to lower emissions densities and rainfall seems less likely to become a regional problem than in the eastern U.S. A possible exception is the oil shale area of western Colorado, where topographic influences may result in the local accumulation of atmospheric sulfates to reduce rainfall pH that might harm vegetation.

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[1] Cogbill, C.V. "The Effect of Acid Precipitation on Tree Growth in Eastern North America," abstract in First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

[2] Abrahamsen, G., and B. Tveite. "Impacts of Acid Precipitation on Coniferous Forest Ecosystems," abstract in First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

[3] Johnson, N.M., R.C. Reynolds, and G.E. Likens. "Atmospheric Sulfur: Its Effect on the Chemical Weathering of New England." Science, Vol. 177 (August 11, 1972), pp. 514-16.

[4] There are four plants in the Mount Storm area, totaling 3,400 megawatts-electric (MWe) and emitting 788,000 tons of SO_2 in 1973. These plants burn high-sulfur coal without scrubbers. The Shawnee plant in Tennessee is rated at 1,750 MWe and emits 228,600 tons per year (1973). By contrast, the hypothetical Colstrip power plant will generate 3,000 MWe but will burn low-sulfur or medium-sulfur coal with scrubbers; its yearly emissions will be 27,807 tons.

C. Low-Level Effects

Atmospheric dispersion alone will likely result in low-level effects around most or all of the large facilities sited in the eight-state study area. In some areas, especially where dispersion is rapid (as in Wyoming), sulfur additions may be so small as to exert no detectable influence on either soil sulfur levels or plant productivity. Slightly larger sulfur inputs may enter the sulfur cycle through direct absorption by plants as SO_2, dry fallout, or rain scavenging.

12.5.6 Summary of Regional Ecological Impacts

The effects described above will change some existing pattern of stresses to aquatic and terrestrial ecosystems. Consumptive water use will result in flow depletion on some rivers. Especially vulnerable are the San Juan, the White, the Upper Colorado, and the Yellowstone. Cumulative impacts will also have adverse effects on the lower Colorado and Missouri. In-stream flow needs to protect aquatic ecosystems have not been established for most of these rivers, but it is expected that withdrawals could produce adverse impacts in several drainages. In addition to the physical impact of flow reduction, loss of dilution capacity increases the risk of harmful impacts due to the discharge of municipal effluents, agricultural runoff, and contaminated groundwater discharge. However, increased salinity does not appear to be a serious ecological problem. Construction of water supply systems may involve placing reservoirs on smaller tributary rivers and streams. These reservoirs can be beneficial in that they will trap sediment, provide fishery habitat, and can be used to regulate downstream flows. However, they also may interfere with spawning runs, destroy valuable riparian habitat, and build up excessive nutrient enrichment from agricultural runoff.

Increased backcountry recreational pressure may become a serious problem to some terrestrial ecosystems, especially high alpine areas, high- and mid-elevation mountain valleys, and adjacent desert watercourses. These habitats are both critical to maintaining present levels of ecological diversity and limited in extent. The heaviest population-related impacts will occur in the Black Hills, the Bighorn Mountains, and the mountainous areas surrounding the Colorado oil shale deposits.

Because of the extensive land use for strip mining in the Northern Great Plains, reclamation will be important. Reclamation success depends primarily on the extent and timing of rainfall, soil type and overburden characteristics, and the resiliency of plant and animal communities in restoration. The Southwestern deserts will be most difficult to reclaim because of poor rainfall, soil characteristics, and overgrazing. Revegetation will probably be successful in the remainder of the eight-state region, but wildlife abundance and diversity will be reduced if grazing or crop production are the major reclamation objectives.

Development of large numbers of SO_2 emission sources over the western region is not expected to result in widespread damage to vegetation. Although the fate of sulfates in the air is poorly understood, comparison with recorded cases suggests that acid rainfall is unlikely to become a widespread problem. Acute damage to vegetation is expected only where rough terrain causes plume impaction. The oil shale area of western Colorado is the only region in which multiple sources are expected to result in cumulative impacts which could be chronically damaging to vegetation over areas of more than 1 or 2 square miles.

12.6 HEALTH EFFECTS

12.6.1 Introduction

The energy facilities deployed in our several scenarios will produce pollutants potentially harmful to health. As indicated below, these health effects depend on the technologies deployed, where they are located, levels of development, and the pathways that potentially toxic materials may follow. In the following discussion, we identify the potential for health effects from: several criteria air pollutants; toxic trace elements; radioactive materials; and organic compounds. Several other potential health-related effects, such as those resulting from changed demographic patterns or exposure to noise, are discussed in Sections 12.4, 12.8, and 12.9.

12.6.2 Selected Criteria Air Pollutants

Ambient air quality standards have been established for the six most common air pollutants: sulfur dioxide, (SO_2), particulates, carbon monoxide, hydrocarbons (HC), oxides of nitrogen (NO_x), and oxidants. These are frequently referred to as "criteria pollutants" to distinguish them from other emissions not yet covered by air quality standards. Five of these pollutants are emitted directly from conversion facilities; oxidants are viewed as secondary pollutants because the mix known as oxidants results from reactions in the atmosphere.

Ambient air quality standards have been established on a dual basis. Primary standards are designed for the protection of public health. Secondary standards are more restrictive in that they are protective not only of the public health but also of environmental components such as vegetation, materials, and aesthetics.[1] Much of the following discussion compares our findings against these ambient air quality standards.

A. Sulfur Dioxide

SO_2 can aggravate a variety of respiratory problems, such as asthma and bronchitis, especially in susceptible populations such as the aged, premature infants, and those suffering lung or heart deficiencies. However, there is disagreement as to the levels required to produce these effects.

Present SO_2 levels are low in most rural locations where energy development may occur, between 2 and 20 micrograms per cubic meter ($\mu g/m^3$). Development of energy facilities, particularly power plants, will contribute to higher SO_2 levels as summarized in Sections 3.2 and 12.2. However, the increase from either energy facilities or urban activities will be below both primary and secondary standards for all averaging times.[2] In western Colorado, plume impaction on unpopulated elevated terrain will cause primary standards to be violated.

Alternative scrubber efficiencies significantly affect SO_2 concentrations. If scrubbers are not used, areas other than those located in rough terrain would experience plume impaction that could result in concentrations exceeding the ambient standards designed to protect human health.

Even with 80-percent sulfur removal, a potential health problem can result from exposure to sulfates. Whether this is a problem depends largely on the assumptions used to assess the conversion rates of SO_2 to sulfate and the sulfate levels which are damaging to health. Rate estimates vary from 1- to 20-percent conversion of SO_2 to sulfate per hour.[1] Twenty-percent conversion rates are associated with oil-fired power plants.[2] If conversion rates are 10 percent per hour, 24-hour ambient sulfate levels are as much as two times greater than those projected to produce increases in mortality according to Environmental Protection Agency studies (Table 12-52).[3]

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[1] There is considerable disagreement concerning the validity of these standards. There is general agreement that the fundamental bases of these standards, especially the epidemiologic studies which form the primary technical bases, are generally inadequate and subject to a substantial margin of uncertainty. There are those who contend that the standards are unnecessarily conservative and restrictive, as well as others who maintain that there is an inadequate margin of safety in the standards, notably in terms of susceptible populations.

[2] In western Colorado, values may exceed standards in some areas during conditions which do not favor dispersal. On a regional scale of development, however, the locations of these areas are not known.

Measurements of HC are not available in most rural areas but high background HC levels (130 μg/m^3) have been measured in the oil shale area of Northwestern Colorado and may occur elsewhere. The sources of this HC include vegetation, biological activity, evaporation from subsurface petroleum deposits, and present urban industrial activity.

Most HC are generally inoffensive to humans at the levels encountered even in urban, polluted atmospheres. Some HC are toxic to plants at low levels. Others, notably the polynuclear aromatics (PNA), may be cancer-producing even at low levels; however, this remains to be demonstrated at the levels found in urban air. Except for these HC standards, controls have been developed primarily to limit photochemical smog.

Some existing urban areas exceed the current federal 3-hour ambient air quality standard for HC due to automotive emissions. Scenario data summarized in Section 3.2 indicate that the standard will be violated in many areas throughout the West, in part because of the existing high background levels. The major sources of HC are urban activities and fugitive losses from synthetic fuels plants and fuel storage facilities, with power plant operations being a minor contributor.

The installation and operation of large fossil fuel and synthetic fuel facilities will also open the possibility of introducing PNA compounds into areas that have probably been relatively free of such contaminants. Particulate collection systems should remove most of the PNA's, but some may be released. However, PNA's should not present a major hazard to the general public.

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[1] U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere. *Review of Research Related to Sulfates in the Atmosphere*. Committee Print. Washington, D.C.: Government Printing Office, 1976.

[2] These faster rates of conversion may be due to the finer particle size associated with oil-fired power plant emissions.

[3] U.S., Environmental Protection Agency. *Position Paper on Regulation of Atmospheric Sulfates*, EPA 450/2-75-007. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

TABLE 12-62: HEALTH EFFECTS AND ASSESSMENT PROJECTIONS FOR SULFATES

Assessment Projections Scenario[a]	Sulfate Concentration $\mu g/m^3$	
	Conversion Rate[a]	
	1%	10%
Kaiparowits/Escalante	2.2	22
Navajo/Farmington	0.8	8
Rifle	1.5	15
Gillette	.5	5
Colstrip	.9	9
Beulah	1.1	11
Health Effects[b]	**Levels Producing Health Effects**	
Aggravation of Asthma	6-10	
Increased chronic bronchitis	14	
Increased acute respiratory disease	10-25[c]	

$\mu g/m^3$ = micrograms per cubic meter

[a] Conversion rates vary for different technologies and are dependent on particle size and other factors. Rates for coal-fired power plants have been reported at 1-3 percent per hour, and rates for oil-fired power plants are as much as 20 percent per hour.

[b] U.S., Environmental Protection Agency. *Position Paper on Regulation of Atmospheric Sulfates*, EPA 450/2-75-007. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[c] U.S., Council on Environmental Quality. *Environmental Quality, Sixth Annual Report*. Washington, D.C.: Government Printing Office, 1975.

PHA's, typified by benzopyrene, will also constitute part of the fugitive or stack emissions from the pyrolysis of carbonaceous fuels, including oil shale. These emissions will also pose a hazard for the occupational labor force (see Section 12.6.5).

B. Oxidants

Oxidants in the atmosphere are a product of the photochemical reactions of HC and nitrogen dioxide (NO_2)(among other materials) activated by solar energy. The process is augmented in situations where pollutants accumulate by virtue of topographic and/or meteorological factors. Although oxidants could become a problem in the oil shale region due to HC emissions, the photochemical process is so complex that predictions of levels or locations where smog may be a health problem are not possible.

C. Nitrogen Dioxide and Other Oxides of Nitrogen

Two important forms of NO_x are nitric oxide and NO_2. NO_2 is more stable and is a lung irritant in acute exposures (4-6 hours) at levels as low as 0.5 parts per million (ppm)(1,000 ug/m^3).[1] Some studies have indicated diminished lung function and possible cancer-producing effects from NO_x. Studies in Chattanooga, Tennessee form an important basis for current EPA standards and are compared with scenario results in Table 12-63.[2] There apparently will not be a health problem from NO_x alone. Although short duration exposures (3-24 hours) were not computed, on the basis of other pollutant modeling, concentrations would probably not approach 1,000 ug/m^3.

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[1] Argonne National Laboratory, Energy and Environmental Systems Division. *A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resources Impacts, and Health Effects*, Draft. Argonne, Ill.: Argonne National Laboratory, 1977.

[2] Chapman, R.S., *et al*. "Chronic Respiratory Disease." *Archives of Environmental Health*, Vol. 27 (September 1973), pp. 138-42; U.S., Department of Health, Education and Welfare, Public Health Service, National Air Pollution Control Administration. *Chattanooga, Tennessee-Rossville, Georgia Interstate Air Quality Study*, 1967-68, Publication No. APTD-0583. Durham, N.C.: National Air Pollution Control Administration, n.d.; and Shy, C.M., *et al*. "The Chattanooga School Children Study: Effects of Community Exposure to Nitrogen Dioxide; Incidence of Acute Respiratory Illness." *Journal of the Air Pollution Control Association*, Vol. 20 (September 1970), pp. 582-88.

TABLE 12-53: PEAK NITROGEN DIOXIDE CONCENTRATION FOR SCENARIO LOCATIONS, 1990 (24 hour average measured in micrograms per cubic meter)

Location	Source	
	Urban	Facility
Kaiparowits	26	11
Farmington	48	6.5
Rifle	NC	4.4
Gillette	41	4.6
Colstrip	16	3.6
Beulah	24	5.7
Federal Standard	100	
Acute Biological effects	1,000 (4-6 hours)	

NC = not calculated

D. Particulates

There is a significant natural background level of airborne particulates in all areas, especially arid environments (see Section 12.2). Very wide variations occur; the range is 1-600 μg/m^3 or more and is a function of the arid conditions and occasional dust storms. Thus, the 24-hour federal primary standard of 260 μg/m^3 is probably exceeded on such occasions. Additionally, when particulates are present with gaseous air pollutants, such as sulfur dioxide, particulates may worsen the toxic effects.[1]

Over the six scenarios, energy facilities will contribute 18-152 μg/m^3 to ambient air particulate loading, and urban expansion will contribute about 30-100 μg/m^3. Fugitive dirt from mines was not modeled. Because ambient concentrations periodically exceed standards, emissions from facilities and urban expansion may create a potential health problem. The particles emitted from energy facilities will be small (below 1-3 microns in average particle diameter by weight) and will remain in the atmosphere over long distances (hundreds of miles). Because of their size, these particles will be capable of deep penetration of the respiratory tract, when inhaled, and will thus offer the maximum potential for harm to animals, including humans. The particles will also be capable of aggravating the effects of gaseous pollutants, such as SO_2, which will become even more significant if the particles contain the types of toxic components described in the following section.

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[1] Argonne National Laboratory, Energy and Environmental Systems Division. *A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resources Impacts, and Health Effects*, Draft. Argonne, Ill.: Argonne National Laboratory, 1977.

12.6.3 Toxic Trace Element Emissions

Conversion of fossil fuels to electricity and synthetic fuels can result in the discharge of "toxic substances". By definition, these substances are much more toxic per unit weight than are the criteria pollutants. The toxic substances discussed below are lead, mercury, cadmium, arsenic, and vanadium.

Lead is present as a natural background substance in airborne particulates, coal, and oil shale, but it is essentially absent from petroleum. The average adult has a daily intake of 300 μg of lead, with about 90 percent via ingestion and 10 percent via respiration. However, gastrointestinal absorption is only about 10 percent, whereas the pulmonary route permits an absorption of 30-50 percent.[1] Thus, airborne lead could account for up to half the total lead absorbed.[2] In view of the steadily increasing annual pollution of air and soils with lead from motor vehicles exhaust, accumulation and toxicity in exposed human beings may occur.[3] Adult or chronic lead poisoning requires months or years to occur and depends on increased exposure to lead. At present, there is concern that exposure to even very low levels of lead will produce subtle central nervous system pathologies, especially in children.

Increased emissions of lead from energy facilities and an expanded population can be significant both in terms of direct exposure to humans and because airborne lead will settle to the ground and enter the food web. However, the lead emitted from energy facilities will probably be minute as compared to that resulting from the expanded population's use of motor vehicles burning leaded gasolines. If lead anti-knock compounds are removed from gasoline, the power plant emissions could become more significant, although overall risk is reduced.

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[1] Schroeder, H.A., and I.H. Tipton. "The Human Body Burden of Lead." _Archives of Environmental Health_, Vol. 17 (December 1968), pp. 965-78.

[2] Goldsmith, J.R., and A.C. Hexter. "Respiratory Exposure to Lead: Epidemiological and Experimental Dose-Response Relationships." _Science_, Vol. 158 (October 6, 1967), pp. 132-34.

[3] _Ibid_.

Mercury occurs in coal, petroleum, and probably in oil shale. Depending on the combustion system and ancillary air pollution control devices, 10-90 percent of the contained mercury can be emitted to the atmosphere. This mercury can be converted to the more toxic organic form by microorganisms. These compounds can then be concentrated in food webs. Exposure to elevated mercury levels in foods produces nervous system disorders and death.[1] The Food and Drug Administration (FDA) has established a 100 parts per billion standard for mercury levels in food.

The level of mercury emitted to the atmosphere by energy facilities is unlikely to constitute a hazard from direct exposure or ingestion. However, intrusion of mercury into the aquatic food web raises possibilities of contamination of fish used as human food. For example, in the Kaiparowits scenario (Chapter 6), mercury can reach Lake Powell from the facilities by direct fallout from emissions and by runoff. Mercury deposition from the hypothetical Kaiparowits power plant alone ranges from 16 to 480 pounds of mercury entering the lake each year, or 1-27 percent of the present estimated rate of addition from natural sources.[2] Current levels in some predatory fish in Lake Powell exceed the standard of 500 ppm, and the energy facility emissions have been estimated to cause increases of 10-50 percent above this value, depending on number of plants, locations, and coal characteristics.[3]

Cadmium is found in coal and oil shale but is absent from petroleum. Cadmium is known to be highly toxic as particulates or fumes; it accumulates in the human kidney and liver, acts on the circulation system,[1] irritates the lung (producing emphysema),[2] and at higher exposures causes damage to the excretory system.[3] Some of these effects occur at concentrations of 500-2,500 $\mu g/m^3$ (0.5-2.5 milligrams per cubic meter [mg/m^3]) over as little as 3 days.[4] Lower levels may be associated with high blood pressure or stomach and intestinal disorders. It is unlikely that any chronic poisoning would result from combustion or pyrolysis of coal containing low levels of cadmium because most of the metal should be captured in the ash. However, because of the possible role of cadmium in producing hypertension and because it accumulates in humans, a possible health hazard exists.

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[1] Pettyjohn, Wayne A. "Trace Elements and Health," in Pettyjohn, Wayne A., ed. *Water Quality in a Stressed Environment: Readings in Environmental Hydrology*. Minneapolis, Minn.: Burgess, 1972, pp. 345-46.

[2] U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Impact Statement: Proposed Kaiparowits Project*, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[3] Standiford, D.R., L.D. Potter, and D.E. Kidd. *Mercury in the Lake Powell Ecosystem*. Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1973, p. 16.

The toxicity of arsenic depends on its chemical form. Metallic arsenic is thought to be non-toxic, while arsine (AsH_3, a colorless gas) is extremely toxic.[5]

Arsenic is suspected of being a carcinogen. Arsenic exposure from coal combustion or pyrolysis emissions should not result in poisoning, but the possibility of increased risk of cancer exists. Arsenic deposited in the aquatic environment may undergo microbiological transformation similar to what has been observed with mercury.

Vanadium is present in coal, petroleum, and oil shale. The production of residual petroleum fuels results in a concentration of the vanadium compounds which then are released during combustion. Vanadium has low toxicity in most forms, although there are some associations between airborne vanadium and respiratory disease. Vanadium dioxide acts as an acid in aqueous solution and when inhaled contributes to respiratory irritation.[1] Most cases of respiratory effects have resulted from exposures of 1-50 $\mu g/m^3$ in dusty air.[2] In 1967, the annual average of airborne vanadium in non-urban western locations was approximately 0.003 $\mu g/m^3$,[3] making the dose of 1-50 $\mu g/m^3$ many thousand times greater than ambient concentrations. Data correlating exposures to these ambient concentrations to document toxicity are not available. This element is potentially toxic because of its involvement in respiratory disease and because it is a "new" or introduced element in the local environment.

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[1] Schroeder, H.A. "Cadmium, Chromium, and Cardiovascular Disease." Circulation, Vol. 35 (March 1967), pp. 570-82.

[2] Bouhuys, A., and J.M. Peters. "Control of Environmental Lung Disease." New England Journal of Medicine, Vol. 283 (September 10, 1970), pp. 573-82.

[3] Piscator, M., K.L. Beckmans, and A.B. Tryckerier, eds. Proteinuria in Chronic Cadmium Poisoning. Stockholm: 1966.

[4] Schroeder, H.A. Cadmium, Zinc, and Mercury. Air Quality Monograph No. 70-16. Washington, D.C.: American Petroleum Institute, n.d.

[5] U.S., Department of Health, Education, and Welfare, Public Health Service. Preliminary Air Pollution Survey of Arsenic and Its Compounds. Raleigh, N.C.: Public Health Service, 1969.

12.6.4 Radioactive Materials

A. Radioactivity in Coal Ash

Exposure to radiation from energy facilities considered in this study may take several forms, including exposure to disposal piles, mine environments, and particulate emissions. A brief identification of some factors affecting radiation exposure in these selected categories is provided below.

Radioactivity in coal is highly variable, as shown in Table 12-64. Reported values for Radium-226, a major source of this radioactivity, generally range from 0.001 to 1.3 picocuries per gram (pci/g) in the U.S.[4] When coal is burned, most of the radium remains with the ash and is therefore concentrated. Radium-226 concentrations have been reported in various coal

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[1] Stokinger, H.E. "Vanadium," in Patty, F.A., ed. Industrial Hygiene and Toxicology, Vol. 2. New York, N.Y.: Wiley-Interscience, 1963, pp. 1171-82.

[2] Lewis, C.E. "The Biological Actions of Vanadium, II." Archives of Industrial Health, Vol. 19 (1959), p. 497.

[3] Athanassiadis, Y.C. Air Pollution Aspects of Vanadium and Its Compounds. National Air Pollution Control Administration. Bethesda, Md.: Litton Systems, Inc., 1969.

[4] Jaworowski, A., et al. "Artificial Sources of Natural Radionuclides in the Environment," in Adams, J., W.M. Lowder, and T.F. Gesell, eds. Natural Radiation Environment, CONF-720805-P2. Washington, D.C.: U.S., Energy Research and Development Administration, 1972, pp. 809-18.

TABLE 12-64: RADIOACTIVITY IN COAL
(picocuries per gram)

Coal Sample Location	Ra-226	Ra-228	Th-220	Th-232
Appalachian	3.0	2.4	2.0	0
Utah	1.3	0.8	1	0
Wyoming	0	1.3	1.6	0
Japan	0	1.5	1.6	0
Alabama	2.3	2.2	2.3	0
Tennessee Valley Authority	4.25	2.05	2.05	2.05
Australia	7.98	0	0	0
Bartsville	2.3	3.1	0	3.1
Colbert	3.1	6.9	1.6	6.9
Poland	2[a]	0	0	0
Widow's Creek	1.6	2.7	2.8	2.7
Montana	2.9[a]	0.8	0.8	0.8

Ra = Radium Th = Thorium

Sources: Eisenbud, M., and H.G. Petrow. "Radioactivity in the Atmospheric Effluents of Power Plants That Use Fossil Fuels." *Science*, Vol. 144 (April 17, 1964), pp. 288-89; Martin, J.E., E.D. Harward, and D.T. Oakley. "Radiation Doses from Fossil Fuel and Nuclear Power Plants," *International Atomic Energy Agency Symposium, New York, 1970*, Report SM-146/19. Vienna: International Atomic Energy Agency, 1971, pp. 107-25; Jaworowski, A., *et al.* "Artificial Sources of Natural Radionuclides in the Environment," in Adams, J., W.M. Lowder, and T.F. Gesell, eds. *Natural Radiation Environment*, CONF-720805-P2. Washington, D.C.: U.S., Energy Research and Development Administration, 1973, pp. 809-18; Bedrosian, P.H., D.G. Easterly, and S.L. Cummings. *Radiological Survey Around Power Plants Using Fossil Fuel*, Report EERL 71-3. Washington, D.C.: U.S., Environmental Protection Agency, 1971.

[a] Assuming 15 percent ash content.

ashes, ranging from 2.1 to 5.0 pci/g with a mean of 3.8 pci/g;[1] other investigators have reported up to 8.0 pci/g.[2]

Depending on the disposition of the ash retained by the collectors, opportunities may exist for radioactivity to enter the environment. If the ash is simply accumulated in piles, opportunities exist for re-suspension of dust, emanation of Radon-222,[3] and leaching of radioactivity from the piles to local surface waters. No data are available on these potential releases.

B. Radioactive Materials from Uranium Mining and Milling

A more serious environmental problem than coal refuse piles are tailing piles from uranium milling operations which may contain several thousand times as much radium as ordinary soils. Exposures from uranium tailings piles pose a significant health risk to distances of 1 kilometer.[4] In addition, underground mining for uranium has resulted in occupational exposures resulting in six- to nine-fold increases in lung cancer.[5] During the past 15 years, controls have reduced exposure to radon gases in uranium mines 10- to 100-fold.[6]

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[1] Eisenbud, M., and H.G. Petrow. "Radioactivity in the Atmospheric Effluents of Power Plants That Use Fossil Fuels." *Science*, Vol. 144 (April 17, 1964), pp. 288-89.

[2] This may be compared with a typical value of 1.0 picocuries per gram for ordinary soils.

[3] Martin, J.E. "Comparative Population Radiation Dose Commitments of Nuclear and Fossil Fuel Electric Power Cycles," in *Proceedings of the Eighth Midyear Topical Symposium of the Health Physics Society: Population Exposure*, CONF-741018. Washington, D.C.: U.S., Atomic Energy Commission, 1974, pp. 317-326.

[4] Swift, Jerry J., and James M. Hardin, and Harry W. Calley. *Potential Radiological Impact of Airborne Releases and Direct Gamma Radiation to Individuals Living Near Inactive Uranium Mill Tailings Piles*. Washington, D.C.: U.S., Environmental Protection Agency, Office of Radiation Programs, 1976.

[5] Schurgin, Arell S., and Thomas C. Hollocher. "Radiation-Induced Lung Cancers Among Uranium Miners," in Union of Concerned Scientists, ed. The Nuclear Fuel Cycle: *A Survey of the Public Health, Environmental, and National Security Effects of Nuclear Power*, rev. ed. Cambridge, Mass.: MIT Press, 1975, pp. 9-40.

[6] *Ibid.*

TABLE 12-65: ESTIMATED ANNUAL AVERAGE AIRBORNE PARTICULATE MATTER
(micrograms per cubic meter)

	Page		Escalante		Glen Canyon	
Year	Navajo	A1/A2[a]	Navajo	A1/A2[a]	Navajo	A1/A2[a]
1980	0.1	0	0.05	0	0.1	0
1990	0.1	0.1	0.05	0.15	0.1	0.1
2000	0.1	0.1	0.05	0.15	0.1	0.1

[a] Contribution due to hypothesized plants at Kaiparowits and Escalante

G. Radiation Exposure from Coal Combustion

Airborne radioactivity due to coal combustion may be estimated by multiplying radioactivity in the fly ash times the airborne concentration of the fly ash. As an example, Table 12-65 gives the estimated particulate concentrations for the Kaiparowits/Escalante scenario due to existing and new power plants for each town. Table 12-66 gives the estimated airborne radioactivity concentrations in the three towns for the years 1990 and 2000. Lung doses

TABLE 12-66: ESTIMATED ANNUAL AVERAGE AIRBORNE RADIOACTIVITY DUE TO COAL COMBUSTION IN 1990 AND 2000

	Radioactivity Concentration (picomicrocuries per cubic meter)[a]						
Town	U^{238}	U^{234}	Th^{230}	Ra^{226}	Th^{232}	Ra^{228}	Th^{228}
Page	0.6	0.6	0.6	0.6	0.7	0.5	0.4
Escalante	0.6	0.6	0.6	0.5	0.7	0.5	0.4
Glen Canyon	0.6	0.6	0.6	0.6	0.7	0.5	0.4

Ra = radium   Th = thorium   U = uranium

[a] 10^{-18} curie per cubic meter.

TABLE 12-67: ESTIMATED INDIVIDUAL LUNG DOSES DUE TO ATMOSPHERIC RADIOACTIVITY PRODUCED BY COAL COMBUSTION IN PAGE, ESCALANTE, AND GLEN CANYON

Isotope	Estimated Dose (urem per year)
U^{238}	0.2
U^{234}	0.2
Th^{230}	1
Ra^{226}	0.5
Th^{232}	2.6
Ra^{228}	0.8
Th^{228}	3

Ra = radium
Th = thorium
U = uranium

calculated[1] for the seven most important radioisotopes found in coal as well as the total estimated dose, are shown in Table 12-67. The health effect usually associated with inhalation of insoluble radioactive particulates is cancer of the lung. A risk rate of 1.2 cases per year per million persons per rem has evolved based on several studies at higher doses and dose rates.[2] Assuming an average exposure period of 30 years, a risk of 36 lung cancer cases per million is reached at one rem exposures. For calculated doses in Table 12-67, an individual has a risk of 1 in 3×10^{-10} of contracting cancer in any year.

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[1] International Commission on Radiological Protection. Recommendation of the International Commission on Radiological Protection on Permissable Dose for Internal Radiation, Report No. 2. New York, N.Y.: Pergamon, 1959.

[2] National Academy of Sciences/National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Washington, D.C.: National Academy of Sciences, 1972.

12.6.5 Hazard from Chemicals in Synthetic Fuels Facilities

A. Introduction

Oil shale retorting and upgrading, coal gasification, and coal liquefaction processes all involve compounds which can be identified as known or probable cancer-causing agents (carcinogens and co-carcinogens).[1] English workers regularly exposed to raw shale oil and to lubricating oil made from shale have showed a high incidence of scrotal and skin cancer.[2] Skin cancers have also been found in workers exposed to shale-derived tars, light oil, waxes, and cutting oils.[3] However, in contrast with the British experience, oil shale industries in Estonia, Brazil, and Sweden have not reported increased incidences of cancer among workers. No skin cancers were detected in the small-scale Bureau of Mines shale oil demonstration plant near Rifle, Colorado although there was a high incidence of benign skin lesions. Cancer death rates more than 300 times those of the general population have been recently reported for workers on the tops of coke ovens.[4] Experience in the 1950's with a coal liquefaction plant operated by Union Carbide in Institute, West Virginia showed that, despite efforts to educate workers to the hazards of unnecessary contact with oils and instruction in decontamination practices, skin cancer during 7 years of operation occurred at 16-37 times the rate previously reported in the literature.[5] Air samples showed as much as 18.70 micrograms per 100 cubic meters of the known cancer producing PNA HC benzopyrene on plant premises, three orders of magnitude higher than that in a typical urban environment with heavy automobile traffic.[1] In Japan, Britain, and Sweden, excess cancers of various organs have been noted in workers producing gas from coal in various processes.[2]

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[1] Freudenthal, R.I., G.A. Lutz, and R.I. Mitchell. *Carcinogenic Potential of Coal and Coal Conversion Products*, Battelle Energy Program Report. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories, 1975.

[2] Commoner, B. "From Percival Pott to Henry Kissinger." *Hospital Practice*, Vol. 10 (1975), pp. 138-41.

[3] Auld, S.J.M. "Environmental Cancer and Petroleum." *Journal of the Institute of Petroleum*, Vol. 36 (April 1950), pp. 235-53.

[4] Lloyd, J.W. "Long-Term Mortality Study of Steelworkers: V. Respiratory Cancer in Coke Plant Workers." *Journal of Occupational Medicine*, Vol. 13 (February 1971), pp. 53-68.

[5] Sexton, R.J. "The Hazards to Health in the Hydrogenation of Coal: I. An Introductory Statement on General Information Process Description, and a Definition of the Problem," pp. 181-86, and "IV. The Control Program and the Clinical Effects," pp. 208-31. *Archives of Environmental Health*, Vol. 1 (September 1960).

These observations establish increased cancer risks associated with both shale oil and coal-conversion processes, but it is not possible to generalize immediately from these cases to the installations planned for the western U.S. Both the specific processes and their scale of operation differ. Recent federal requirements for maintaining worker safety have changed conditions.

There is a relative lack of data on the large number of potential cancer-causing chemicals present in waste and process streams. This section will summarize selected organic substances which are known or suspected to cause cancer and which may be found in the process streams and wastes of shale and coal-conversion processes. Then, the avenues of contact of workers or nearby humans are outlined.

B. Cancer-Causing Agents in Oil-Shale Processing

Oil shale itself is not generally thought to be cancer producing; the organic portion of the shale rock is mainly low-molecular-weight organic material with little aromatic hydrocarbon content. However, retorting produces a variety of molecules including PNA HC's suspected of producing cancer. Tests on Colorado oil shale gave a distillate containing 2 percent PNA's.[3] Upgrading shale oil reduces its carcinogenicity by breaking down these components. However, the residues may contain relatively high concentrations of PNA's.[4]

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[1] Ketcham, N.H., and R.E. Norton. "The Hazards to Health in the Hydrogenation of Coal: III. The Industrial Hygiene Studies," Archives of Environmental Health, Vol. 1 (September 1960), pp 194-207.

[2] Kawai, M., et al. "Epidemiologic Study of Occupational Lung Cancer." Archives of Environmental Health, Vol. 14 (1967), pp. 859-64; and Doll, R., et al. "Mortality of Gasworkers with Special Reference to Cancers of the Lung and Bladder, Chronic Bronchitis, and Pneumoconiosis." British Journal of Industrial Medicine, Vol. 22 (January 1965), pp. 1-12.

[3] Not all polynuclear aromatics are carcinogens, but most organic carcinogens found in shale oil are polynuclear aromatics.

[4] Schmidt-Collerus, Josef J. Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations. Denver, Colo.: University of Denver, Research Institute, 1974.

Workers on oil shale plants will be exposed on a regular basis to shale oil in amounts depending largely on the attention paid to housekeeping within the plant. Leaking pump seals will be a major source of fugitive produce losses; especially near groups of pumps, surfaces will tend to become contaminated with a thin film of oil originating from these leaks. Thus, it is possible that a majority of plant workers may come into regular contact with raw and upgraded shale oil. An effort to establish a maximum safe exposure rate will be necessary to specify appropriate housekeeping measures to prevent increased cancer risk. Individuals involved in plant cleaning and maintenance would be in regular contact with the oil. Accidental spills requiring special cleanup efforts could expose some individuals to large quantities of oil, but these events would be infrequent. Because most of these cancer-producing chemicals do not evaporate easily, the health risk from inhalation may be less that that of repeated skin contact with oil films.

Some carcinogens will be emitted in the stack gas from the boilers and retort;[1] these will be dispersed into the atmosphere around the plant. While exposure would be regular in areas affected by poor plume dispersion, there is no evidence to suggest that the very low concentrations resulting would constitute a significant health hazard.

Spent shale disposal could also expose populations to cancer-causing chemicals. In Estonian spent shale dumps, small unsaturated HC's with less than 25 carbon atoms (some of which could be carcinogenic) may be evolved.[2] Carbonaceous spent shale produced by retorting Colorado oil shale has been shown to contain carcinogens.[3] Workers compacting the spent shale, or maintaining the containment dikes, could be exposed to these substances regularly by inhalation.

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[1] These include the polynuclear aromatic carcinogens 7,12 dimethylbenz(a)anthracene. Dibenz(a,j)anthracene, 3 methylcholanthrene, benz(c)phenanthrene, Benzpyrenes, benzanthracenes, chrysene, and carbazoles, among others (Barrett, R.E., *et al.* *Assessment of Industrial Boiler Toxic and Hazardous Emissions Control Needs*, Final Report, Contract no. 68-02-1323, Task 8. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories, 1974.)

[2] Schmidt-Collerus, Josef J. *Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations*. Denver, Colo.: University of Denver, Research Institute, 1974.

[3] *Ibid.*

Finally, process waters and various aqueous plant wastes will be contaminated with PNA's and other hydrocarbons. These wastes may be used to slurry or wet the spent shale, and workers involved may be exposed to the carcinogens through contact or inhalation.

C. Cancer-Causing Agents in Coal Conversion

As is the case with oil shale processing, the raw materials for coal conversion generally have low quantities of cancer-causing substances. However, the processes of gasification and liquefaction result in the formation of complex organic molecules, some of which may cause cancer. Synthesis gas prior to upgrading to pipeline quality contains more hazardous substances than the final product.[1] Therefore, the greatest plant hazards will be from fugitive losses of raw synthesis gas and from the cleanup procedures (sulfur recovery, tar separation) designed to remove harmful substances. To a lesser extent, fugitive emissions from storage and blending of the final product may constitute a hazard.[2] Workers stationed in these areas would receive regular exposure to fugitive emissions in amounts largely determined by housekeeping standards. Emissions from the plant stacks would, like those of shale processing, emit some organic carcinogens as vapors or entrained on particulate matter. Fugitive emissions of liquefied coal could occur in the same manner as shale-oil losses, and the same considerations with respect to exposure apply. In addition to the liquid product itself, recycled solvent oils used in the process could escape into the working environment.

Solid wastes from coal conversion include an ash discharged into a settling pond as a wet-solid. If process wastewaters (such as quench water) are used to slurry the ash, workers might contact a number of toxic compounds. Potentially more hazardous solid wastes are the chars and tars produced as process residues. In many instances, these could be burned in utility boilers. However, care would be needed in preventing contact with these materials in transfer from reactor to boiler.

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[1] Of the major gasification processes, the highest risk of occupationally related cancer is thought to be associated with high-pressure, fixed-bed processes. (Freudenthal, R.I., G.A. Lutz, and R.I. Mitchell. *Carcinogenic Potential of Coal and Coal Conversion Products*, Battelle Energy Program Report. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories, 1975.)

[2] Cavanaugh, E.C., *et al. Potentially Hazardous Emissions from the Extraction and Processing of Coal and Oil*, EPA-650/2-75-038. Austin, Tex.: Radian Corporation, 1975.

Since large quantities of carbonaceous solid wastes are not produced by coal conversion, there will be less chance for environmental health hazards arising from fugitive dusts and contamination of ground or surface waters than will be the case with oil shale. Nevertheless, evaporation ponds in which quench water, plant drain water, or other wastes contaminated with heavy coal fractions are stored could introduce carcinogens into the environment outside the plant through a rupture of the seal permitting seepage or through windblown dust, if the ponds are not properly covered or revegetated after abandonment.

12.6.6 Summary of Health Effects

The selected health effects summarized in this chapter are highly dependent on both the kinds of technologies and the locations where they are deployed. For example, underground uranium mining and milling may pose a cancer hazard to those humans within the immediate vicinity of energy development, but these technologies generally do not produce the significant levels of criteria air pollutants associated with fossil fuel development. In both cases, however, occupational and public exposure to health hazards have changed significantly during the past decade and are highly dependent on circumstances surrounding individual developments.

Among criteria air pollutants, SO_2, particulates, HC, and oxidants have the potential to become health problems. The extent of the SO_2 problem from power plants and oil shale conversion facilities will depend largely on the rate of conversion of SO_2 to sulfates and on the emissions controls deployed. Where terrain is rugged or poor dispersion potential exists, such as in the Rocky Mountains, the potential health hazards will be greatest. The federal primary air standard for HC will be violated by coal liquefaction, oil shale retorting facilities, natural gas facilities, and urban sources. Concentrations can be as much as 325 times the standards. This will contribute to the formation of oxidants, which are a primary health problem. The 24-hour federal primary ambient air standard for particulates is already frequently violated by blowing dust; the addition of fine particulates from surface mining, the transport of coal by trains, and particulate emissions from conversion facilities will exacerbate this potential health problem. There is apparently no direct health hazard associated with NO_x from the facilities and locations considered.

Trace elements may also pose a potential health problem. For example, mercury concentrations in some sport fish already exceed standards established by the FDA. Additions of mercury from power plants will aggravate this problem.

12.7 TRANSPORTATION IMPACTS

12.7.1 Introduction

Development of energy resources in the eight-state study area will produce solids, liquids, gases, and electricity as energy forms. Since most of the ultimate consumers are located in other areas of the country an extensive transportation network will be required.

To assess the impacts of transportation of these energy resources, the Stanford Research Institute (SRI) energy model[1] was used for the Nominal Demand, Low Demand, and Low Nuclear Availability cases described in the Introduction to Part II. The model divides the U.S. into geographic regions; resources, demands, and costs are specified on a regional basis. Cost of transportation alternatives are also specified, and on the basis of delivered costs, the model determines the quantity of energy which will be transported by each alternative among the supply and demand centers. The transportation links in the model extend from the energy resource area to the centroids[2] of the energy demand regions. No attempt was made to simulate the complex network of links between numerous cities and towns.

12.7.2 Transportation Modes[3]

Raw coal can be transported by rail, slurry pipeline, barge, and truck. The only modes considered in this analysis are rail and slurry pipeline because trucks cannot handle the quantities to be shipped over long distances and the lack of navigable waterways in the West precludes consideration of barges.[4]

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[1] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] A centroid of a region is calculated as the point which minimizes the average distance to all other points in the region.

[3] Under subcontract to the University of Oklahoma, a special transportation analysis has been undertaken and is available as an appendix to this report. See Rieber, Michael, and Shao Lee Soo. Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission (Appendix B of this report).

[4] Much western coal may be transferred to water-borne modes when it reaches as far east as the Mississippi. See, for example, "Great Lakes Terminal Provides a Twelve-Month Market." Coal Age, Vol. 18 (August 1976), p. 89.

Liquid fossil fuels (crude oil, shale oil, and coal syncrude) can be moved by pipelines, barges, and rail. Since most oil will be transported over long distances by pipeline, the analysis was limited to this mode. Natural gas and synthetic natural gas will also be transported almost entirely by pipeline.

For the purpose of this study, electrical transmission consists of electricity generated at mine-mouth plants and transported via alternating or direct current at high voltage until interconnected with already established distribution networks.

12.7.3 Coal Unit Trains

A coal unit train is a dedicated, single-purpose train, usually consisting of 4 or 5 locomotives pulling 100 hopper cars of 100 tons capacity each. The coal is loaded onto the train at a fast-loading facility located at the mine. The train travels directly to the delivery point where fast unloading facilities clear the cars. All cars remain coupled to the train at all times. The train returns directly to the mine to obtain another load. The unit train management technique allows the trains to run continuously, and the train stops enroute only for refueling and inspections.

The number of unit trains that will be traveling from western resource basins to various demand centers for the Nominal Demand case for the year 2000 are shown in Figure 12-8. For the Low Demand case, the number of required trips will be less; for the Low Nuclear Availability case, the number of trips will increase substantially; and for the Powder River-Chicago run, the number of trips will reach 80 trains per day.

Several direct effects on people located along the route can be identified. At grade crossings along the route, automobiles and other street traffic will be halted during train passages. Passage time will be 3 minutes for a 100-car train approximately 1 mile in length traveling at 20 miles per hour. For the Powder River-Chicago route, 43 trips per day will be required in the year 2000 for the Nominal case.[1] If a double-track line and equal spacing of train movements are assumed, a loaded train will pass any given crossing approximately every 34 minutes. During this time interval, an empty train will return from the opposite direction. Given these frequencies, a crossing would be blocked 18 percent of the time.

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[1] In the interest of internal consistencies, this estimate is based on Stanford Research Institute's assumed average of 17 million British thermal units per ton for all western coal. In other words, 1 Q of energy is embodied in each 59 million tons.

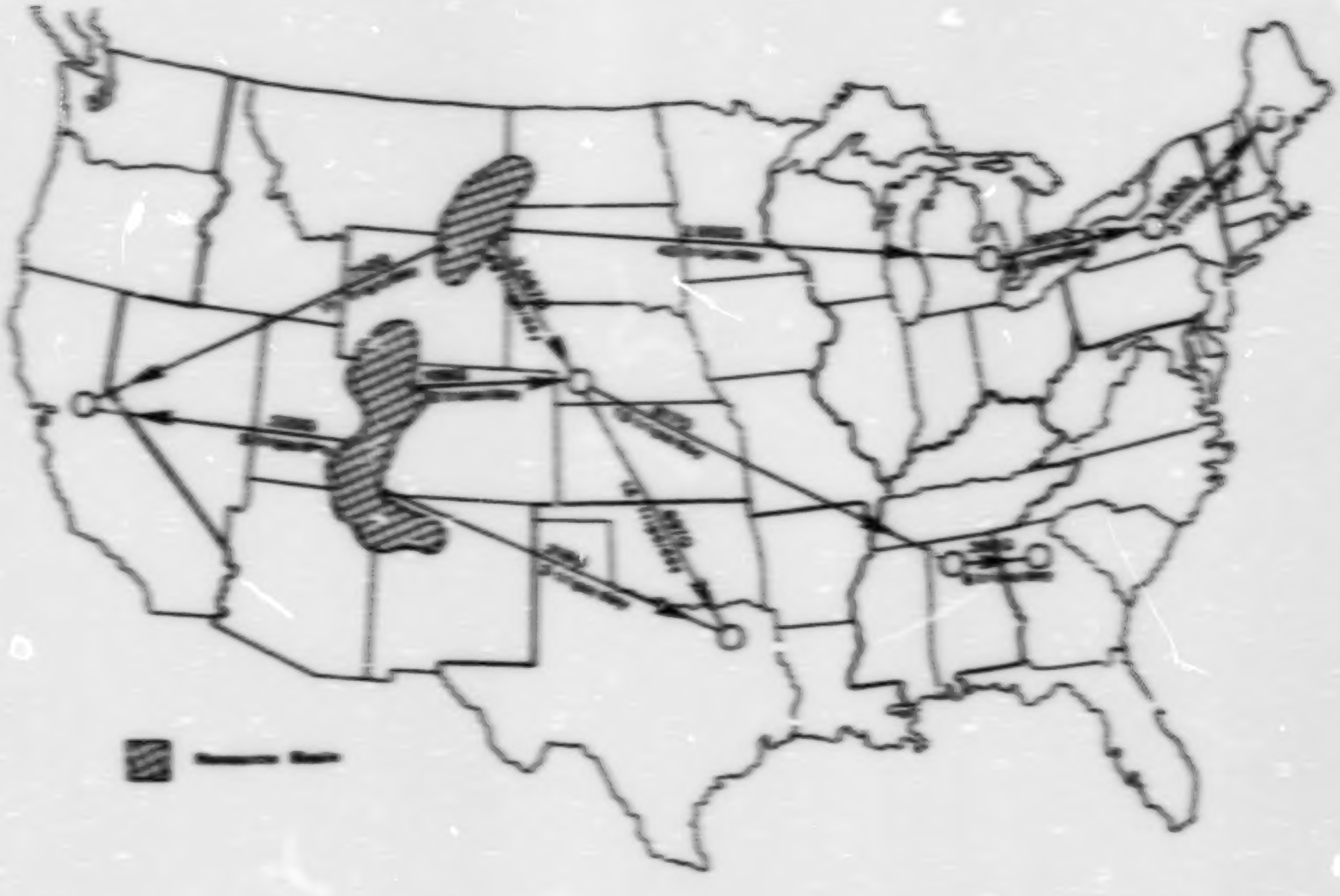

FIGURE 12-8: UNIT TRAIN COAL ENERGY TRANSPORTED FROM WESTERN REGION IN THE YEAR 2000, NOMINAL DEMAND CASE

However, it is unlikely that a single existing rail line would accommodate the total traffic. Spreading the traffic over several roughly parallel rail lines (at least in the more densely populated areas) would mitigate the impact to a certain extent. It is more likely that a new, double-tracked line would be constructed which could minimize grade crossings by building overpasses or avoiding most towns. Assuming a 100-foot right-of-way is required to construct new double tracking to each of the demand centers indicated in Figure 12-8 (a total of 7,365 rail miles), nearly 90,000 acres of land would be required. This land requirement does not include feeder or distribution lines, nor does it include space for coal handling equipment.

Another example demonstrates the effect of heavy train traffic. Assuming that the 37,800 loaded unit trains projected to transport coal from the Powder River region in the year 2000 pass in the proximity of a single city (e.g., Gillette, Wyoming), then one loaded unit train would pass, on the average, every 14 minutes. An unloaded train would also return, on the average, during this interval. The probability of this occurrence is admittedly low but serves to illustrate the resultant intra-city congestion. In the Low Nuclear Availability case, the impact will be exacerbated because some 60,800 loaded unit trains (per year) are projected to originate in the region. Impacts would be mitigated to the extent that the train routes go in three different directions and that an array of tracks would probably be constructed to serve the coal mines scattered throughout the region.

Another direct population impact would be noise. Our analysis indicates that 1,134,000 people reside within 1 mile on either side of a railroad from Colstrip, Montana to Chicago, Illinois. As shown in Section 12.9, noise levels from a single unit train will be annoying up to approximately 1 mile from the track. Projected loaded unit train movements over this route vary from 33 to 80 unit trains per day for the Low Demand and Low Nuclear Availability cases, respectively. This means that more than one million people would be disturbed between 10 and 33 percent of every day by train noise.

Animal populations will also have problems with railroad crossings. Heavy unit train traffic posses a hazard to large animals (e.g., antelope) moving in herds over large areas during the year. They cannot be expected to pass rail lines quickly, and numbers of them could be killed in collisions with trains. Most domesticated livestock will be protected from the train hazard by fencing, but this will restrict the migration of wild animals.

Railroads have been spending less and less on track maintenance over the last two decades. Results of a recent study for the Federal Energy Administration indicated that to restore

71 percent of the national rail lines (rails and ties) to normal condition will require $4.1 billion. A total expenditure of $12 billion has been estimated for complete restoration. It was not determined whether this restoration process would enable existing lines to carry the increased tonnage required for coal unit trains. However, the track maintenance problem under heavy coal loading has been cited as a major consideration in determining practical track capacity.[1] Therefore, existing rail lines may not be able to accommodate the frequency and tonnage of projected coal unit rail traffic. Some lines have been constructed specifically for unit train traffic,[2] but for many lines, new ballast, ties, and heavier rails will probably be required.

Assuming that 33,000 miles of track would be required for coal movement, this upgrading would require 5 million tons of steel and, with a reconstruction cost of $100,000 per mile, would require $3.3 billion.[3] Assuming that 18,400 miles of new double track would be required by 2000 and that new construction would be $300,000[4] per mile and require 372 tons of steel, $5.5 billion and 6.8 million tons of steel would be required. (These estimates are in addition to the requirements for slurry pipelines, which are detailed in the next sub-section.)

One advantage frequently identified with trains is that the railroads would be available for moving other freight. This would be true for most rail lines until about 1990 (and probably for a few rail lines after 1990). However, some lines would be saturated almost from the beginning, especially if they have been poorly maintained. Also, the unit train concept is predicated on fast, scheduled movements. Any additional trains using the lines will have to schedule around unit train traffic. There is a disagreement as to when rail line saturation would occur, and some analysts argue that it will not be until 70 million tons per year (tpy) are moved on one doubletrack line.[1] The new track estimates given above were predicted on a saturation point of 25 million tpy. The larger capacity assumption would mean only 6,600 miles of new track instead of 18,400, with corresponding reductions in cost and materials.

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[1] U.S., Federal Energy Administration. *Project Independence Blueprint, Final Task Force Report: Analysis of Requirements and Constraints on the Transport of Energy Materials*, Vol. 1. Washington, D.C.: Government Printing Office, 1974.

[2] Doran, Richard K., Mary K. Duff, and John S. Gilmore. *Socio-Economic Impacts of Proposed Burlington Northern and Chicago North Western Rail Line in Campbell-Converse Counties, Wyoming*. Denver, Colo.: University of Denver, Research Institute, 1974.

[3] FEA. *PIB Report: Transport of Energy Materials*.

[4] Blair, A. Ross, and Paul D. Martinka. "Western Coal Transportation, A Challenge." *Mining Congress Journal*, Vol. 61 (April 1975), pp. 40-45.

Current locomotives and freight car fleets may be inadequate.[2] This would affect not only coal transportation but the transport of other commodities as well. An examination of hopper car availability nationally during the past decade suggests that limitations imposed by steel, equipment manufacturing capacity, and available capital will significantly affect the shipping industries and the capacity of railroads to provide the equipment that would be required. The total U.S. capacity of hopper cars declined by over 1 million tons in the 1969-1974 period.[3] The Department of Transportation announced in mid-1972 that an additional 130,000 cars were needed to meet the 1972 car shortage. The estimate of required investment was $2.3 billion.[4] Forecasts show that a 33-percent growth in rail-freight transportation between 1971 and 1980 will require about 617,000 cars of 80-ton capacity each. The Department of Transportation also estimated that an $8.8 billion fund will be required to keep abreast of future demands. Even if funds are available, at least 2 years lead time would be required to build these cars.[5] The economic impacts of this construction are considered in Section 12.4.8.

Although there is no reported locomotive shortage, the development of western energy resources might create one. Lead time

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[1] U.S., Federal Energy Administration. *Project Independence Blueprint, Final Task Force Report: Analysis of Requirements and Constraints on the Transport of Energy Materials*, Vol. 1. Washington, D.C.: Government Printing Office, 1974.

[2] U.S., Congress, Senate, Committee on Commerce. *To Alleviate Freight Car Shortage*, Senate Report 92-982 on S. 1729, 92d Cong., 2d sess., 1972.

[3] Blair, A. Ross, and Paul D. Martinka. "Western Coal Transportation, A Challenge." *Mining Congress Journal*, Vol. 61 (April 1975), pp. 40-45.

[4] U.S., Congress, Senate, Committee on Commerce. *To Alleviate Freight Car Shortage*, Senate Report 92-982 on S. 1729, 92d Cong., 2d sess., 1972.

[5] Boyce, Allan R. Private Communication. Burlington Northern, Energy, Metallics, and Chemicals Section. August 28, 1974.

TABLE 12-68: UNIT TRAINS REQUIRED FOR THREE LEVELS OF DEVELOPMENT[a]

Year	Level of Development	Unit Trains[b]	Steel[c] (1,000 tons)	Capital[d] (Millions of Dollars)
1980	Low	156	624	846
	Nominal	189	756	1,024
	Low Nuclear	256	1,024	1,388
1985	Low	241	964	1,306
	Nominal	313	1,252	1,696
	Low Nuclear	474	1,896	2,569
1990	Low	276	1,104	1,496
	Nominal	358	1,432	1,940
	Low Nuclear	565	2,260	3,062
2000	Low	380	1,520	2,060
	Nominal	512	2,048	2,775
	Low Nuclear	850	3,400	4,607

[a] Assumes an average train speed of 30 miles per hour and an average loading and unloading time of five hours.

[b] Each consisting of 4 locomotives and 100 hopper cars.

[c] Assumes 4,000 tons of steel per unit train. Track steel excluded.

[d] Assumes $530,000 per locomotive and $33,000 per hopper car (constant 1975 dollars).

for locomotive construction is about 1 year.[1] Calculations have been made to determine the number of locomotives and hopper cars required to satisfy transportation requirements for expected western energy development based on various train speeds and loading/unloading times.[2] Results for each of the three levels of developments are shown in Table 12-68. Table 12-69 shows the

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[1] Engel, A.P. Private Communication. General Electric Co., locomotive Products Department, Domestic Electrification Projects, August 15, 1974; Whittle, T.C. Private Communication. General Electric Co. Transportation Systems Division, September 11, 1974.

[2] Buck, P., and N. Savage. "Determine Unit-Train Requirements." Power, Vol. 118 (January 1974), pp. 90-91.

TABLE 12-69: UNIT TRAIN REQUIREMENTS FOR EXTREME CASES[a]

Year	Case	Unit Trains	Steel (thousands of tons)[b]	Capital[c] (millions of dollars)
1980	Low[d]	129	516	702
	High[e]	341	1,364	1,856
1985	Low	201	804	1,094
	High	627	2,508	3,414
1990	Low	228	912	1,242
	High	752	3,008	2,766
2000	Low	314	1,256	1,709
	High	1,123	4,492	6,114

[a] In-service requirements--no reserves included.

[b] Based on 4,000 tons of steel/train (4 locomotives and 100 hopper cars). No track steel requirements are included.

[c] The capital requirement is based on 4 locomotives per 100-car train, $33,000 per hopper car, and $530,000 per locomotive (constant 1975 dollars).

[d] Based on the Low Demand case, an average of 2 hours for loading and unloading, and an average train speed of 35 miles per hour.

[e] Based on the Low Nuclear Availability case, an average of 5 hours for loading and unloading, and an average train speed of 20 miles per hour.

extremes which could occur under various assumptions as to train speeds and loading times.

12.7.4 Coal Slurry Pipelines

Slurry pipelines are a fairly new mode of coal transportation which can provide cost advantages over coal unit train transport for large volumes and high utilization rates (above 85 percent). The largest slurry pipeline in operation in the U.S. is also the largest in the world: the 273-mile, 18-inch line used to transport some 4.8 million tons of coal per year from the Black Mesa mine in Arizona to a power plant in southern Nevada. Four proposed lines have been announced, one from

Wyoming to Arkansas, one from Colorado to Texas, one from Utah to Nevada, and one from New Mexico to Arizona.[1]

The technology of coal slurry transportation involves grinding the coal to a powder, mixing it with water on a 50-50 weight basis, pumping this mixture through the pipeline, and dewatering the coal at the receiving end. Water scarcity is one of the potentially major obstacles to the development of coal slurry lines from the western U.S. This problem could be lessened by using a closed-loop system, but this could increase overall cost by as much as 15 percent.[2] It has also been suggested that other slurry media, such as liquid fossil fuels (crude oil, shale oil, or coal syncrude) or methanol, be used rather than water. At the receiving end, either the mixture could be burned whole or separated for different uses.

If water is used and not recycled, disposal at the receiving end can create environmental problems. The water must be cleaned before disposal or before use for power plant cooling or other industrial purposes. Other perceived disadvantages of coal slurry pipelines are accidental leaks and lack of operational flexibility. In the case of leaks, the problem portion of the line must be flushed out before repair, thus requiring that the slurry mixture be held in some container, either for reuse or for disposal. Also, lack of operational flexibility can be a problem since the slurry cannot be allowed to settle in the pipeline. Available mitigative measures in cases of reduced demand include reducing the slurry velocity, increasing the water volume, or stockpiling transported coal.

Figure 12-9 indicates the number and routes of slurry pipelines needed to transport western coal for the Nominal case in the year 2000. Each pipeline is assumed to transport 25 million tons of coal per year and thus will require approximately 18,400 acre-feet per year (acre-ft/yr) of water at the pipeline source. For the Nominal case in the year 2000, the 17 pipelines originating in the Northern Great Plains will require approximately 313,000 acre-ft/yr or 23 percent of the water for energy in that area. Approximately 38,000 acre-ft of water will be required by the pipelines originating in the Four Corners states, equivalent to 2.9 percent of the water for energy in the Upper Colorado.[3]

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[1] Western Governors' Regional Energy Policy Office. The Coal Pipeline Alternative. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1975.

[2] Rieber, Michael, and Shao Lee Soo. Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission (Appendix B of this report).

[3] Further details on water use can be found in Section 12.3.

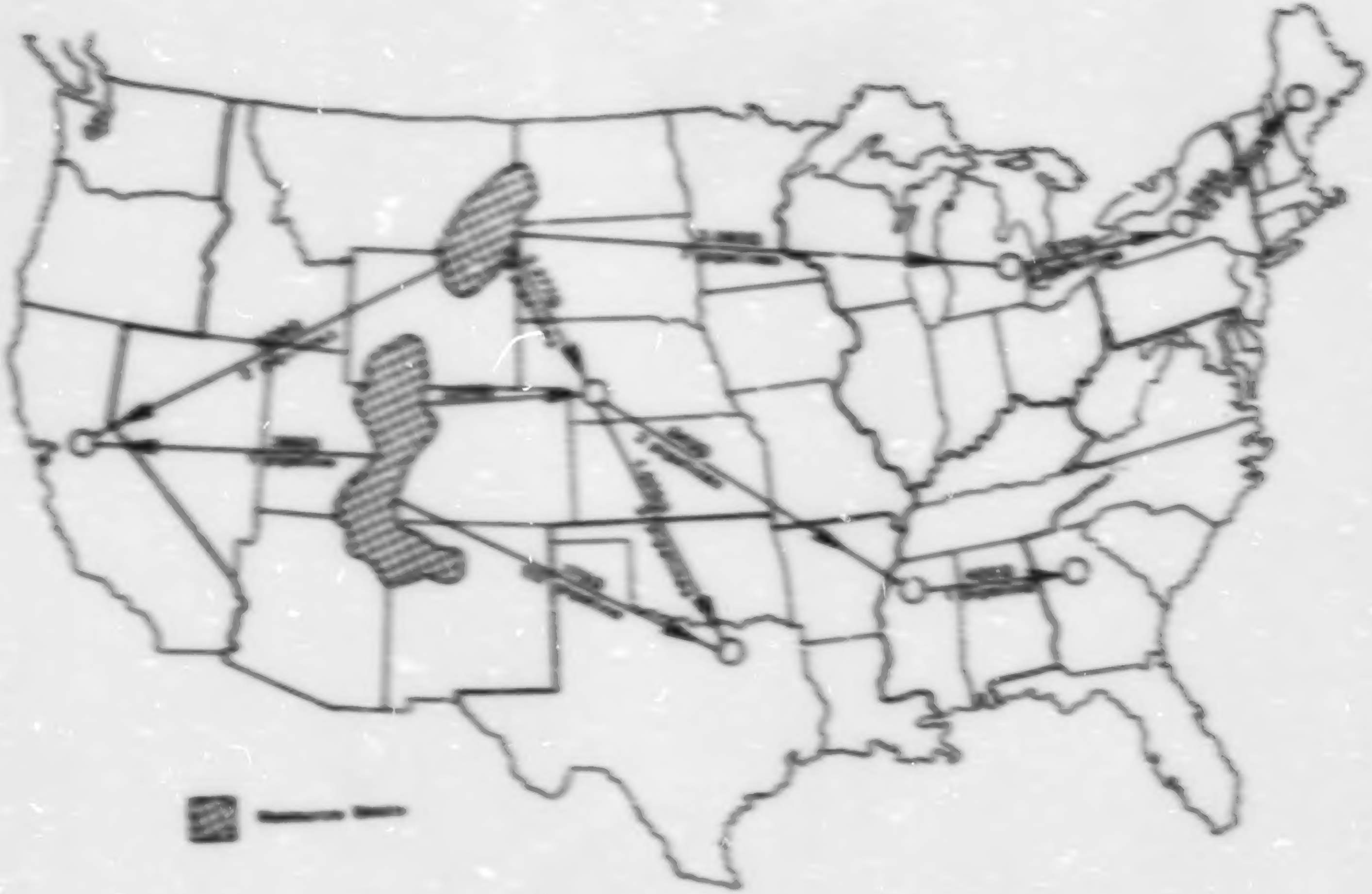

FIGURE 12-9: 2000 COAL SLURRY PIPELINE ENERGY TRANSPORTED FROM WESTERN REGION, NOMINAL DEMAND CASE
(Capacity of each pipeline is assumed to handle 25 million tons per year of coal.)

The Nominal case will require approximately 20,100 miles of 38-inch diameter slurry pipelines by 2000. If a construction cost of $800,000 per mile[1] is used, total construction capital expenditures would be $16.1 billion for the pipelines required in the year 2000 for the Nominal case. (For a construction cost of $1 million per mile,[2] capital expenditures would be $20.1 billion.) These figures range from $12.2 billion for the Low Demand case to $25 billion for the Low Nuclear Availability case. Since pipeline operation is not as labor intensive as unit train operration, a smaller proportion of expense is subject to escalation. It has been reported that only 27.1 percent of pipeline annual costs are subject to escalation, as compared with 98.5 percent for railroads.[3] But by the same token, a higher portion of pipeline costs are capital; hence, commitment must be made before demand levels are confirmed.

Based on steel requirements of 390 tons per mile,[4] 7.8 million, 5.9 million, and 12.2 million tons of steel are required for the Nominal Demand, Low Demand, and Low Nuclear Availability cases, respectively, by the year 2000.

If a 100-foot right-of-way is assumed, approximately 244,000 acres would be occupied by coal slurry lines in 2000 by the Nominal case. Similarly, 184,000 acres and 379,000 acres will be required by the projections for the Low Demand and Low Nuclear Availability cases, respectively. These values do not include land requirements for pump stations or preparation and dewatering facilities.

12.7.5 High Btu Gas Pipelines

Based on the Nominal Demand case, nine gas pipelines of 1 billion cubic feet (bcf) per day capacity will originate in the Northern Great Plains, while four will be required in the Four Corners area (Nominal case) in the year 2000 to transport both natural and synthetic gas. The number of pipelines and routes are shown in Figure 12-10. Data filed with the Federal Power Commission (FPC) show that two major interstate gas pipeline companies have lines currently traversing the Four Corners states with a total yearly capacity of 2,141 bcf, exclusive of added compression or looping which would increase the capacity. Therefore, except for short gathering lines to tie in with these existing trunk lines, it is anticipated that no new pipelines will be required to transport the gas projected to be produced in the Rocky Mountain region for the Nominal case. Existing lines will progressivnly transport less natural gas and more synthetic gas.

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[1] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] Rieber, Michael, and Shao Lee Soo. Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission (Appendix B of this report).

[3] "Coal Pipeline Beats Out Transmission Lines." Electrical World, Vol. 184 (December 1, 1975), p. 58.

[4] U.S., Federal Energy Administration. Project Independence Blueprint, Final Task Force Report: Analysis of Requirements and Constraints on the Transport of Energy Materials, Vol. 1. Washington, D.C.: Government Printing Office, 1974.

Based on the same FPC data, one major gas pipeline with a capacity of 56 bcf per year currently traverses the Northern Great Plains. In addition, the proposed Northern Border Pipeline Company pipeline will traverse the region.[1]

The Nominal case will require that 4 bcf, 201 bcf, and 3.43 trillion cubic feet (tcf) of gas per year be produced in the Northern Great Plains in 1985, 1990, and 2000, respectively. In this case, current lines will be adequate until the late 1980's, but new pipelines with a capacity of 3.37 tcf per year will be required by 2000. For the routes needed, approximately 7,300 miles of 36-inch pipelines costing nearly $2.8 billion[2] will be required by 2000. Assuming a 60-foot right-of-way, approximately 53,000 acres of land will be required.

12.7.6 Liquid Fossil Fuel Pipelines

Liquid fuel flows from the western region to the three refinery regions for the Nominal case in the year 2000 are shown in Figure 12-11. Liquid fuels are composed of crude oil, shale oil, and coal syncrude. The number of nominal-sized 600,000-barrel per day (bbl/day) pipelines which will be required for each route are also indicated.

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[1] U.S., Department of the Interior, Office of Coal Research. Prospective Regional Markets of Coal Conversion Plant Products Projected to 1980 and 1985. Washington, D.C.: Government Printing Office, 1974.

[2] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

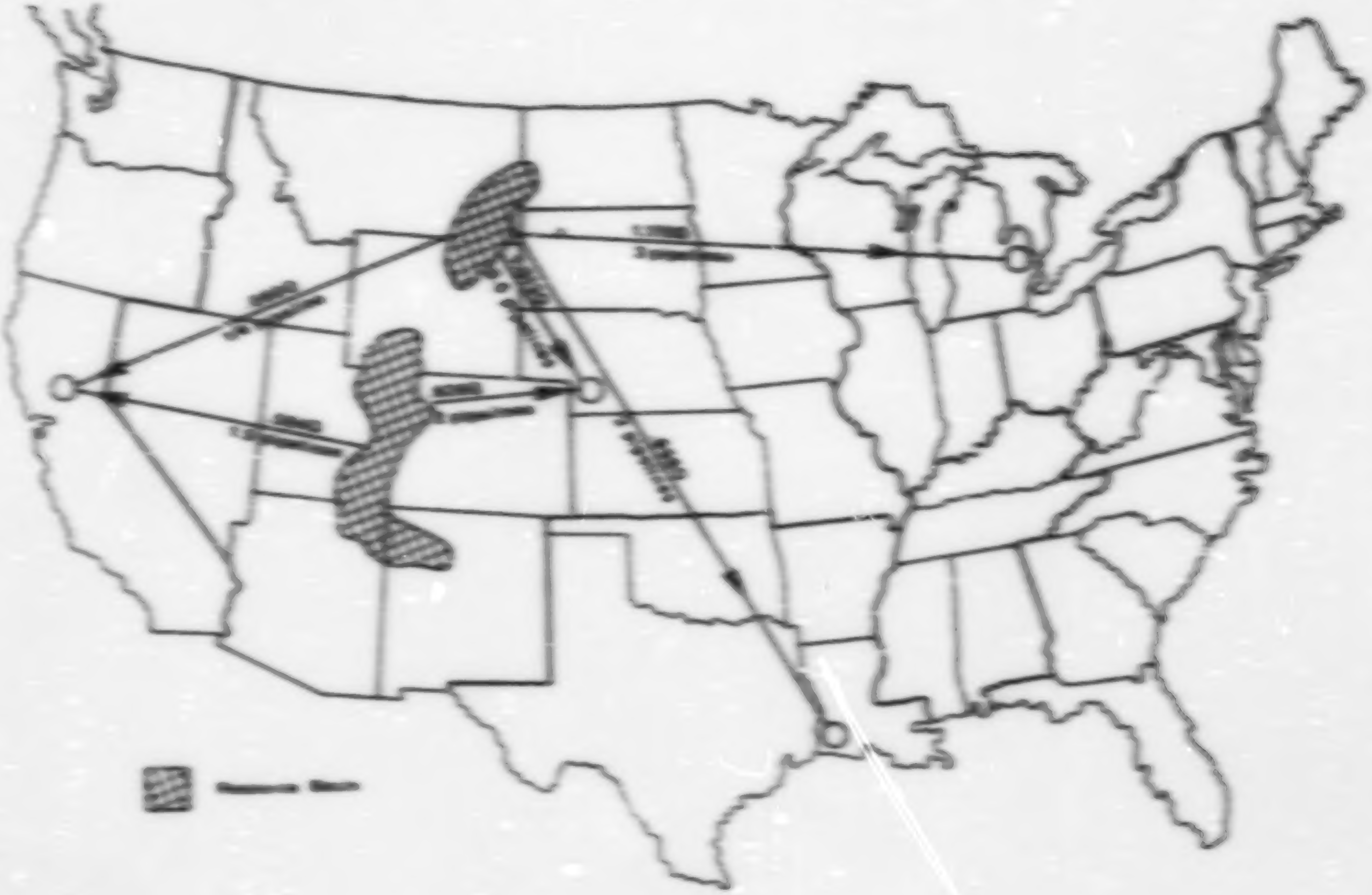

FIGURE 12-10: 2000 HIGH BTU GAS TRANSMISSION FROM WESTERN REGION,
NOMINAL DEMAND CASE
(Capacity of each pipeline is one billion cubic feet per day.)

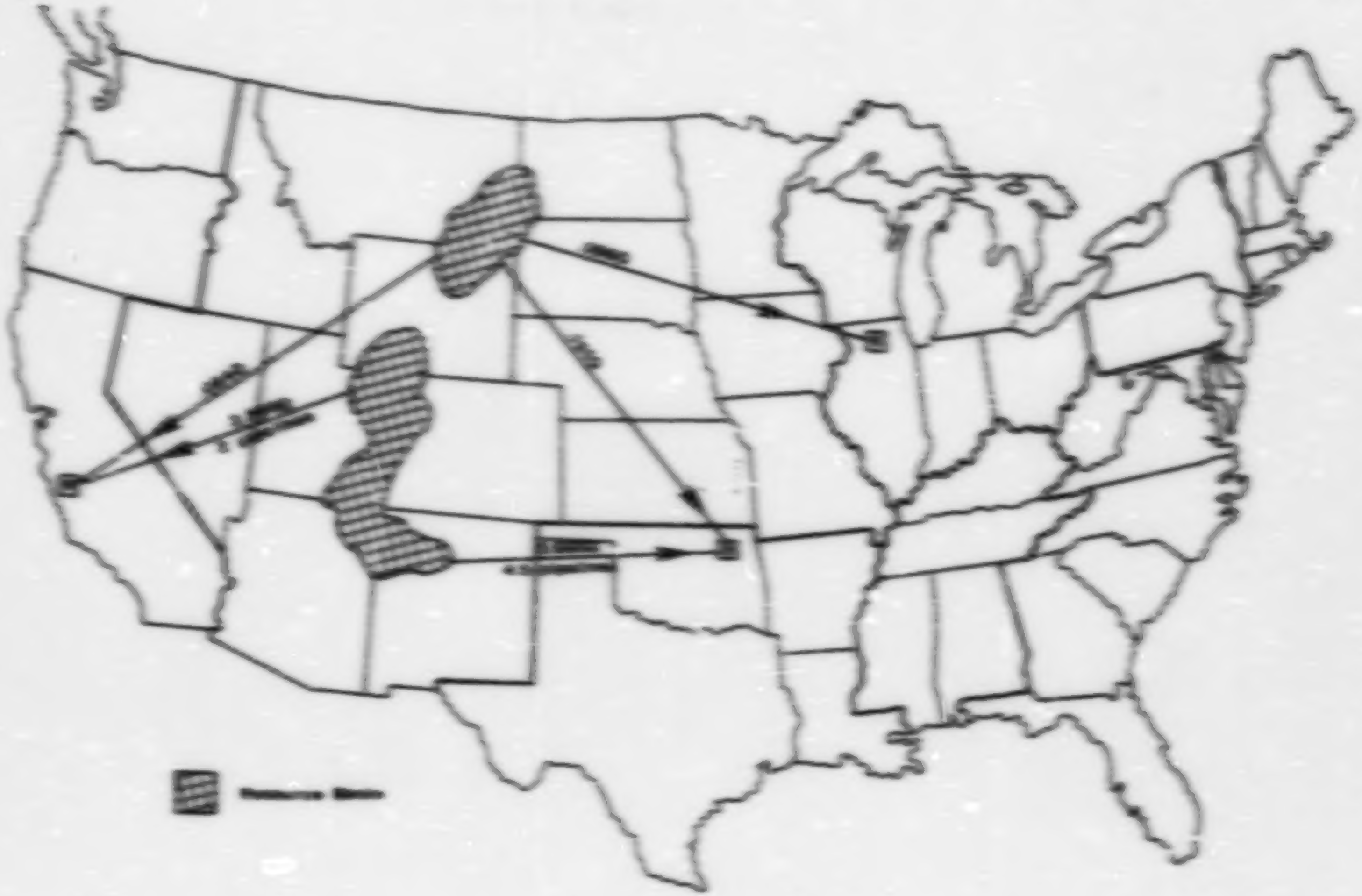

FIGURE 12-11: 2000 LIQUID PIPELINE (CRUDE OIL, SHALE OIL, COAL SYNCRUDE) ENERGY TRANSPORTED FROM WESTERN REGION NOMINAL DEMAND CASE

Existing trunkline capacity from the Northern Great Plains has been estimated as 620,000 bbl/day.[1] In the Nominal case, 142,000 bbl/day will be produced in the year 2000 in the area. Therefore, except for tie-in lines, existing crude oil trunkline capacity should be capable of transporting the projected production of liquid fossil fuels from the Northern Great Plains to refinery centers.

In the Nominal case, the Four Corners area will produce 3.91 million bbl/day of liquid fossil fuels in the year 2000. However, the Interstate Commerce Commission estimates the available crude oil trunkline capacity out of the area as 260,000 bbl/day.[2] As a result, almost all the approximately 2,400 miles of 36-inch pipelines must be newly constructed. Projected construction costs in 2000 are $684 million (1974 dollars).[3] Assuming a 60-foot right-of-way, land requirements will be approximately 17,500 acres.

12.7.7 Electrical Transmission

Electrical energy transmission from the western region for the Nominal case in the year 2000 is shown in Figure 12-12. This electricity is assumed to be generated at the mine-mouth. Transmission is assumed to be by 600-kilovolt (kV), 2,160-megawatt direct current (DC) transmission lines. The number of lines required for each route is indicated in the figure.

Mine-mouth electrical generation for export will require new transmission facilities to tie into existing grid systems because few of the hypothesized mines are located near metropolitan demand centers. For the Nominal case in 2000, approximately 13,000 miles of DC lines (or equivalent carrying capacity in alternating current (AC) lines) will be required. Based on available cost data, the total capital cost for these lines would

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[1] U.S., Department of the Interior, Office of Coal Research. Prospective Regional Markets of Coal Conversion Plant Products Projected to 1980 and 1985. Washington, D.C.: Government Printing Office, 1974.

[2] Ibid.

[3] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

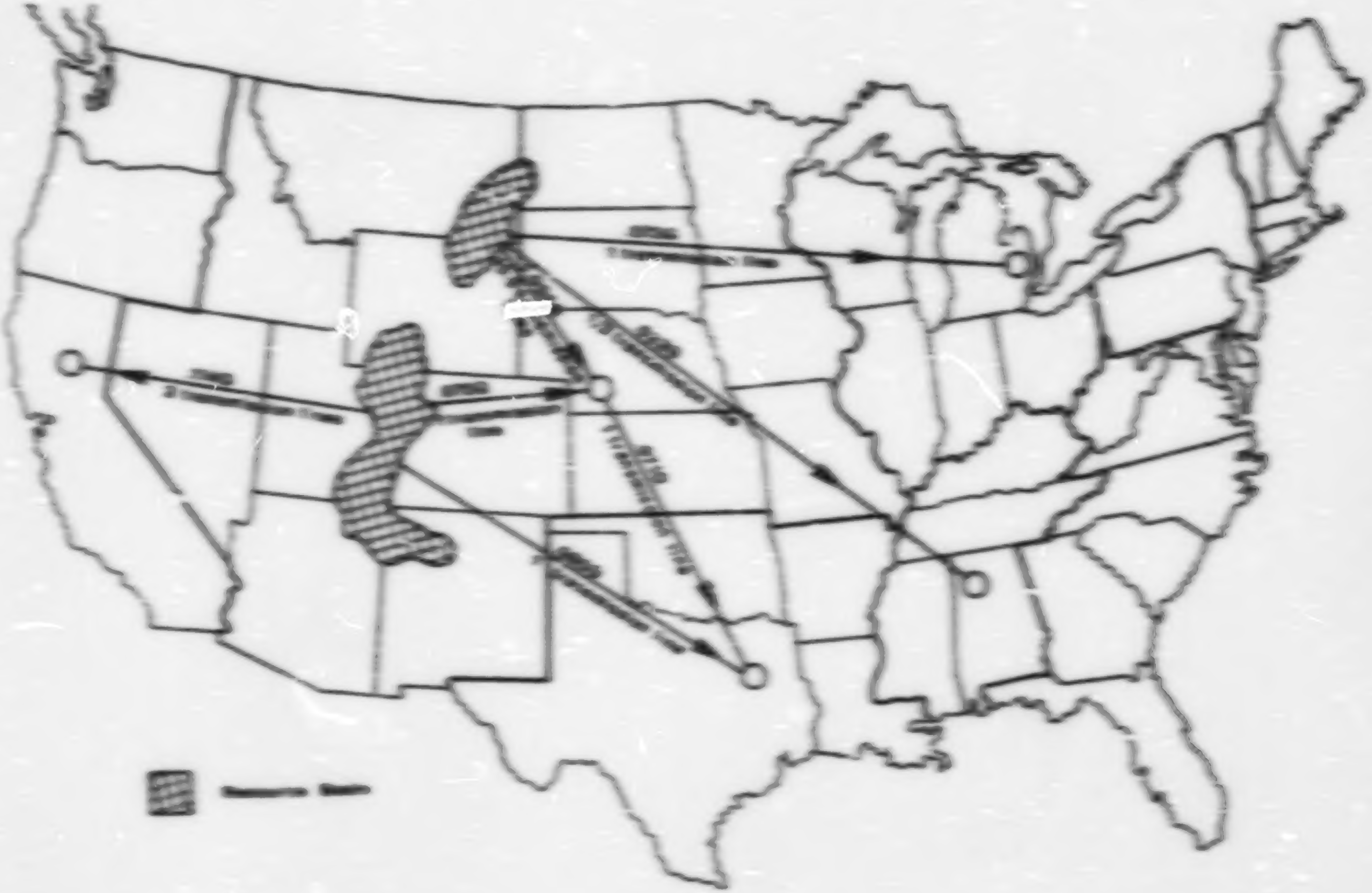

FIGURE 12-12: 2000 ELECTRICITY TRANSMITTED FROM WESTERN REGION, NOMINAL DEMAND CASE

be between $3 billion[1] and $13.2 billion.[2] These values are approximate since transmission line costs are both energy and distance dependent.

The choice between AC and DC transmission is not clear because there are advantages and disadvantages to both systems. DC transmission was selected for the regional scenario analysis because it has potential for lower power losses and reduced environmental impact in the high-volume, long-distance applications considered in this study.

The technology of transmitting electricity via high-voltage direct current (HVDC) lines is still in its early development stages as compared to AC transmission. Consequently, the use of HVDC has been fairly limited. Of the 39,502 circuit miles of overhead extra-high voltage (EHV) transmission lines operational in 1974, only 865 miles were DC lines operating at ±400 kV.[3] It has been estimated that by 1980 approximately 1,670 miles of ±400 kilovolt direct current will be operational.[4]

In general, HVDC transmission lines (whether overhead or underground) can carry significantly higher line loads than their high voltage alternating current (HVAC) equivalents. For example, EHV DC overhead systems can transmit power in the 1,000-6,000 megwatt-electric range without known adverse effects on the environment.[5] For a given line voltage, DC transmission lines incur less transmission losses than AC.[1] The simplicity of the DC transmission line tower design produces fewer land-use and visual impacts.[2] DC overhead transmission line costs, at minimum distances of 400 miles, are approximately 33-percent less than those for a comparable AC transmission line.[3] In the case of underground transmission lines, the cost of installing a DC line is about 50-percent less than the cost of an AC line of the same power rating for a distance greater than 40 miles. Other advantages have also been documented.[4]

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[1] Rieber, Michael, and Shao Lee Soo. Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission (Appendix B of this report).

[2] "Coal Pipeline Beats Out Transmission Lines." Electrical World, Vol. 184 (December 1, 1975), p. 58.

[3] "The Electric Century, 1874-1974." Electrical World, Vol. 183 (June 1, 1974), p. 116.

[4] U.S., Federal Power Commission. 1970 National Power Survey. Washington, D.C.: Government Printing Office, 1971, Part 1.

[5] U.S., Federal Council for Science and Technology, Office of Science and Technology, Energy R&D Goals Study Panel. Electrical Transmission and Systems. Washington, D.C.: Federal Council for Science and Technology, 1972; and Knudsen, N., and F. Iliceto. "Contribution to the Electrical Design of EHVDC Overhead Lines." IEEE Transactions on Power Apparatus and Systems, Vol. PAS-93 (January/February 1974), pp. 233-39.

Although HVDC transmission systems have a number of advantages, their terminal facilities (especially converter-inverter equipment) are complex and expensive. Thus, AC may be preferable in short-distance situations or when several destinations are to be served simultaneously.

Despite the experience gained with HVAC (765-kV) power transmission lines,[5] two basic problems still exist: the electrostatic potential gradient from conductor to ground and the audible noise generated by corona discharge during unfavorable weather conditions.[1] The first problem, normally called electrostatic effects, can cause discomfort and, in some cases, serious shock. These electrostatic effects have been observed to cause skin tingling, movements of body hair, and microsparking from vegetation to a person's legs.[2] This problem can be alleviated by providing an adequate mid-span clearance to ground, installing grounded wires below the energized conductors, fencing off the transmission line right-of-way, or using electrostatic shields in critical locations.

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[1] U.S., Federal Power Commission. *1970 National Power Survey*. Washington, D.C.: Government Printing Office, 1971, Parts 1 and 4.

[2] "The Electric Century, 1874-1974." *Electrical World*, Vol. 183 (June 1, 1974), p. 116; and "UHV Technology Is Rapidly Emerging from the Laboratory and into Actual Service." *Electrical World*, Vol. 183 (July 1, 1974), p. 40.

[3] Martinson, Heine. "Future Applications for HVDC." Paper presented at the 3rd Energy Transportation Conference, 1973.

[4] U.S., Federal Council for Science and Technology, Office of Science and Technology, Energy R&D Goals Study Panel. *Electrical Transmission and Systems*. Washington, D.C.: Federal Council for Science and Technology, 1972; "Electric Century."; FPC. *National Power Survey*; Knudsen, N., and F. Iliceto. "Contribution to the Electrical Design of EHVDC Overhead Lines." *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-93 (January/February 1974), pp. 233-39; Martinson. "HVDC."; and "UHV Technology."

[5] Vassell, Gregory S., Raymond M. Maliszewski, and Norman B. Johnsen. "Experience with the AEP 765-KV System: Part 2--System Performance." *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-92 (July/August 1973), pp. 1337-47.

Audible noise caused by corona discharges result from the accumulation of water droplets on the conductors, creating intensified surface gradients. Corona discharge is observed to be influenced by conductor size, geometrical arrangement of the bundle, phase spacing, height above ground, and the type of conductor material.[3] Corona discharges have caused some public concern about the generation of ozone. However, recent investigations conclude that pollutant concentrations generated by conductor corona on present EHV transmission lines are too low to be deleterious to the environment.[4]

All overhead transmission lines will have a prominent visual impact. For example, single-circuit 1100 kilovolt alternating current test lines are carried by towers that stand about 209 feet high in contrast to existing 500-kV lines on 129-foot towers with the same circuit and tower configurations. Further, the conductor bundles will be large and add to the visual impact. The visual impact can be minimized by using aesthetically pleasing structures and installing the towers so as to reduce line-of-sight effects.[1]

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[1] U.S., Federal Council for Science and Technology, Office of Science and Technology, Energy R&D Goals Study Panel. Electrical Transmission and Systems. Washington, D.C.: Federal Council for Science and Technology, 1972; "UHV Technology Is Rapidly Emerging from the Laboratory and into Actual Service." Electrical World, Vol. 183 (July 1, 1974), p. 49.

[2] "UHV Technology."

[3] Federal Council for Science and Technology. Electrical Transmission; "The Electric Century, 1874-1974." Electrical World, Vol. 183 (June 1, 1974), p. 116; Kolcio, N., B.J. Ware, and R.L. Zagier. "The Apple Grove 750 KV Project Statistical Analysis of Audible Noise Performance of Conductors at 775 KV." IEEE Transactions on Power Apparatus and Systems, Vol. PAS-93 (May/June 1974), pp. 831-40.

[4] Frydman, M., and C.H. Shih. "Effects of the Environment on Oxidants Production in AC Corona." IEEE Transactions on Power Apparatus and Systems, Vol. PAS-93 (January/February 1974), pp. 436-43; and Roach, J.F., V.L. Chartier, and F.M. Dietrich. "Experimental Oxidant Production Rates for EHV Transmission Lines and Theoretical Estimates of Ozone Concentrations Near Operating Lines." IEEE Transactions on Power Apparatus and Systems, Vol. PAS-93 (March/April 1974), pp. 647-57.

Assuming a 200-foot right-of-way, the 13,000 circuit miles projected for the year 2000 will require approximately 315,000 acres. Rights-of-way are usually purchased and then leased for other uses or are obtained through easements. After tower construction, most of the land is normally returned to agricultural or other uses, although questions are being raised about the multiple uses of transmission line corridors.[2]

12.8 NOISE IMPACTS

12.8.1 Introduction

Noise can be defined as any sound that may produce an undesired physiological or psychological effect in an individual or animal or that may interfere with the behavior of an individual or group.[3] Physiologically, noise can temporarily or permanently damage hearing, interfere with speech communications and the perception of auditory signals, disturb sleep, interfere with the performance of complicated tasks, and adversely affect mood. More intangibly, it often can be a source of annoyance.[4]

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[1] U.S., Department of Agriculture and Department of the Interior. *Environmental Criteria for Electric Transmission Systems*. Washington, D.C.: Government Printing Office, 1973; U.S., Federal Power Commission. *Electric Power Transmission and the Environment: Guidelines for the Protection of Natural, Historic, Scenic, and Recreational Values in the Design and Location of Right-of-Way and Transmission Facilities*. Washington, D.C.: Federal Power Commission, 1971; and Litton, R. Burton, Jr. *Landscape Control Points: A Procedure for Predicting and Monitoring Visual Impacts*, Research Paper PSW-91. Berkeley, Calif.: U.S., Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1973; and Western Systems Coordinating Council. *Environmental Guidelines*. Denver, Colo.: Western Systems Coordinating Council, 1971.

[2] Young, Louise B. *Power Over People*. New York, N.Y.: Oxford University Press, 1973.

[3] Korbec, Matthew J. "Noise and Hearing," Preprint from 1972 edition of *Your Government and the Environment*. Arlington, Va.: Output Systems Corporation, 1971.

[4] Miller, James D. *Effects of Noise on People*. St. Louis, Mo.: Central Institute for the Deaf, 1971.

Within recent years, recognition and quantification of these effects have resulted in noise becoming identified as an environmental pollutant that raises both social and health concerns.[1]

The following analysis of noise impacts focuses on illustrative cases considered representative of conditions that may be encountered in the construction, mining, transportation, and operation activities of energy facilities. As a starting point in the analysis, noise levels for four activities are estimated: transporting coal by railroad unit train; constructing a 3,000-megawatt-electric (MWe) power plant; operating a 3,000-MWe power plant; and surface strip mining. These cases were analyzed to determine whether the noise they will produce would be a source of concern for inhabitants located near the sources. Evaluations were based on the equivalent sound level averaged over 24 hours and historical data on the response of humans to these average levels.

12.8.2 Methods and Criteria

Based on many laboratory and field studies, quantitative values of noise level can be related to effects on people. Some 20 different measures of noise have been developed and are used in practice. A particular measure is generally adopted to satisfy the specific objectives of a noise evaluation program.

In evaluations of the impact of environmental noise, Environmental Protection Agency (EPA) criteria were used as the basis for estimating effects from construction, operating, and mining. EPA recommends the use of the long-term equivalent A-weighted sound[2] levels with an adjustment to account for the greater impact that a noise has at night than during the day.[3] The noise level limits considered essential to protect public welfare and safety are presented in Table 12-70.

Additional criteria may be developed based on the efforts required to communicate in the presence of ambient

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[1] White, Frederick. Our Acoustic Environment. New York, N.Y.: Wiley, 1975.

[2] A-weighted sound is a single value measured that approximates sound as processed by the human ear.

[3] The "day-night average sound level" is the mathematically defined measure of average sound level recommended by Environmental Protection Agency.

TABLE 12-70: SOUND LEVELS REQUIRED TO PROTECT PUBLIC HEALTH AND WELFARE[a]

Effect	Level	Area
Hearing loss[b]	$L_{eq}(24)$ -70 dB	All areas
Outdoor activity interference and annoyance	L_{dn} -55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq}(24)$ -55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	L_{dn} -45 dB	Indoor residential areas.
	$L_{eq}(24)$ -45 dB	Other indoor areas with human activities such as schools, etc.

dB = decibel(s)

L_{dn} = the sound level L_{eq} weighed with a 10-dB larger impact for nighttime sounds.

L_{eq} = the sound level averaged over a 24-hour period.

Source: U.S., Environmental Protection Agency, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Washington, D.C.: Environmental Protection Agency, 1974, p. 3.

[a] Table to be read as follows: To protect from a hearing loss effect, the sound level $L_{eq}(24)$ must be less than 70dB in all areas, both indoor and outdoor.

[b] Hearing loss level represents annual averages of daily sound level over a period of 40 years.

TABLE 12-71: SOUND LEVELS PERMITTING SPEECH COMMUNICATION

Listener Distance[a] (feet)	Ambient Sound Level for Speech Communication (dBA)			
	Low Voice	Normal Voice	Raised Voice	Very Loud Voice
1	60	66	72	78
2	54	60	66	72
3	50	56	62	68
4	48	54	60	66
5	46	52	58	64
6	44	50	56	62
12	38	44	50	56

dBA = decibels A-weighted

Source: Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

[a] Distance between speaker and listener.

sound levels. These efforts are shown in Table 12-71 and indicate, for example, that for an ambient sound level of 78 decibels (dB) measured on the A-scale, a very loud voice must be used to communicate with someone only 1 foot away. These criteria are consistent with the effect of noise on telephone communication, where a background noise level above 75 dBA (decibels A-weighted) makes telephone conversation difficult (Table 12-72).

The change in sound level is an important factor in assessing the impact from added noise sources. It is just possible to detect a change in noise level of 2-3 dBA, while a 5-dBA change is readily apparent. An increase in noise level of 10 dBA is equivalent to a doubling of the loudness of the sound.

The effects of noise on wildlife and domestic animals are less well understood. Studies of animals subjected to varying noise exposures in laboratories have demonstrated physiological and behavioral changes, and these reactions are assumed applicable to wildlife. However, no scientific evidence currently correlates the two. Large animals adapt quite readily to high sound

TABLE 12-72: QUALITY OF TELEPHONE USAGE IN THE PRESENCE OF STEADY-STATE MASKING NOISE

Noise Level (dBA)[a]	Telephone Usage
30-50	Satisfactory
50-65	Slightly Difficult
65-75	Difficult
Above 75	Unsatisfactory

[a] dBA = decibels A-weighted

Source: Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

levels. Conversely, loud noise disrupts brooding in poultry and consequently can decrease egg production.[1]

The major effect of noise on wildlife is related to the use of auditory signals. Acoustic signals are important for survival in some wildlife species. Probably the most important effect is related to the prey-predator situation. An animal that relies on its ears to locate prey and an animal that relies on its ears to detect predators are both impaired by intruding noise.[2] The reception of auditory mating signals could be limited and therefore affect reproduction. Distress or warning signals from mother animals to infants (or vice versa) or within groups of social animals could be masked and possibly lead to increased mortality. There are clues that short-term high noise levels may startle wild game birds and stop the brooding cycle for an entire season.[3]

A final suggested noise criterion is the likelihood of community response to noise levels; this is shown in Figure 12-13. If the day-night average sound level is above 65 dB, widespread complaints about the noise can be expected.

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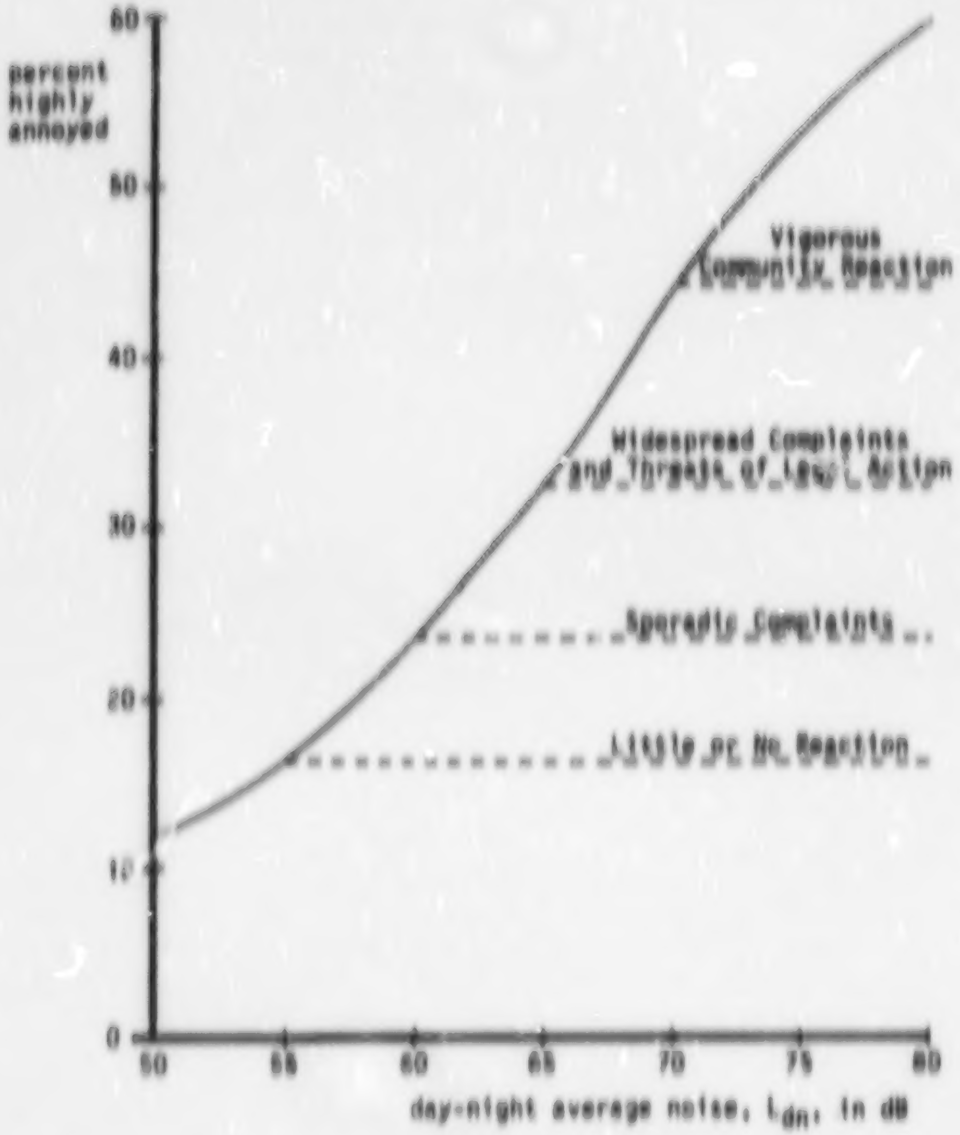
[1] Memphis State University. Effects of Noise on Wildlife and Other Animals. Springfield, Va.: National Technical Information Service, 1971.

[2] Ibid.

[3] Ibid.



Source: Crocker, Malcolm J., and A. John Price. *Noise and Noise Control*, 2 vols. Cleveland, Ohio: CRC Press, 1975.

Figure 12-13: EXPECTED DAY-NIGHT HUMAN RESPONSES AT VARIOUS NOISE LEVELS

In this analysis, noise levels were predicted using a simple model that incorporates information on ambient air and topographic conditions and the properties of energy dispersion in air under these conditions. The results of this model predict energy levels at selected distances from single or multiple sources. The results are presented in terms of day-night equivalent sound levels (L_{dn}).

12.8.3 Rail Transport of Coal[1]

Residents will certainly notice noise created by coal trains passing through their town. In most small western towns there are few buildings to block sound transmission, and the noise level from a passing unit train will be high enough to interfere with outdoor activity and to annoy people for approximately 1 mile on either side of the tracks. One train per day will raise the daily averaged noise measure above the outdoor annoyance level within 800 feet of the tracks. If as discussed in Section 12.7.3., 43 trains per day travel along a given line, the noise impact on people living nearby would be considerable.

Radiated noise characteristics of unit trains have been determined by calculating the noise radiated and its attenuation for each of the engines and cars, then summing the total for various locations away from the track.[2] The dBA as a function of time is shown in Figure 12-14 for three observer distances from the tracks: 100 feet, 1,000 feet, and 3,000 feet. The calculations assume that there are few buildings in the town to block or attenuate sound transmission.

At 100 feet, the separate contributions of the locomotive and the coal cars will stand out clearly. Engine noise will dominate for about a minute, and the peak value will be more than 100 dBA. This noise level will require shouting to communicate with another person at a distance of 1 foot.[3]

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[1] Each coal train is assumed to be about 1 mile long and comprised of 5 diesel locomotives and 100 freight cars. The speed of the train through town is assumed to be 20 miles per hour; thus, it will take about 3 minutes for the entire train to pass by an observer. The capacity of each car is 100 tons for a total of 10,000 tons.

[2] Swing, Jack W., and Donald B. Pies. Assessment of Noise Environments Around Railroad Operations, Report No. WRC 73-5, El Segundo, Calif.: Wyle Laboratories, 1973.

[3] Occupational Safety and Health Administration regulations limit exposure to 100 decibels A-weighted noise to no more than two hours per day.

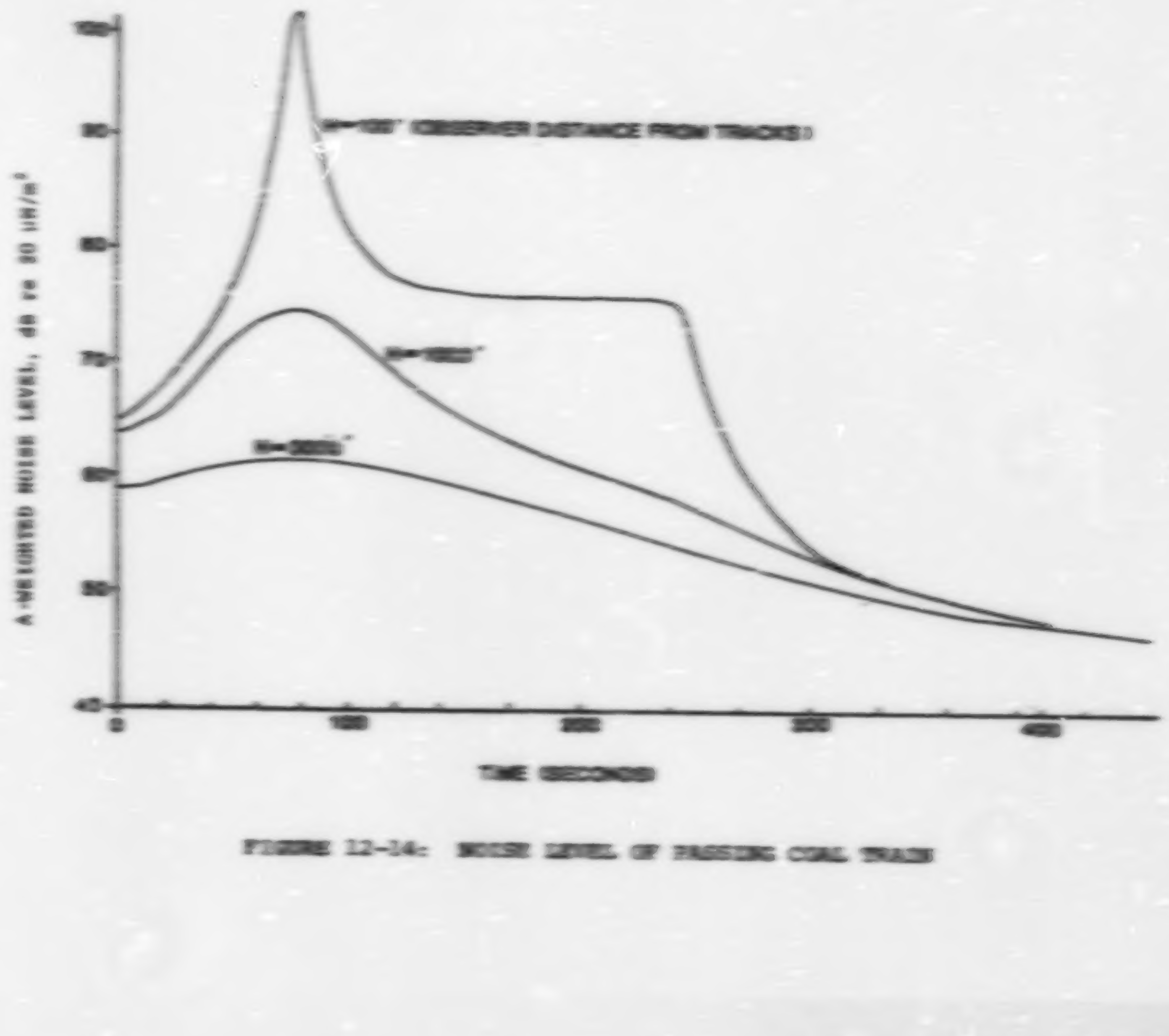

FIGURE 12-14: NOISE LEVEL OF PASSING COAL TRAIN

At 1,000 feet, the noise level will vary more smoothly with time, and the separate contributions of engine and coal car noise will not be so clearly defined. The noise level will be above 55 dBA for about 8 minutes. This is the level specified by the EPA as the "outdoor activity interference and annoyance" threshold. At 3,000 feet, the noise level will still be above 55 dBA for about 6 minutes, but the observed peak level will be reduced to 61 dBA.

As noted earlier, the L_{dn} is useful for predicting community annoyance and reaction. Figure 12-15 shows the predicted L_{dn} values at 100 feet and 1,000 feet as a function of the number of trains per day. Within 800 feet of the tracks, one train per day will cause an L_{dn} of 55 dBA, and some community reaction can be expected. Several trains per day would generate an even greater response. This situation can be expected all along the many rail lines carrying coal from western mines.

12.8.4 Plant Construction

Facility construction noise will be much more localized than rail transport and will be caused primarily by heavy construction equipment. Plant construction noise was assumed to be concentrated in four areas: reservoir, ash disposal area, evaporative ponds, and cooling tower and power block construction. The equipment assumed to be operating in each area was:

Reservoir:	1 crane, 3 bulldozers, 6 dump trucks
Ash disposal area:	1 crane, 2 bulldozers, 4 dump trucks
Evaporative ponds:	1 grader, 2 bulldozers
Cooling tower and power block construction	3 cranes, 6 air compressors 4 rock drills, 10 pneumatic wrenches, 8 welding generators, 3 graders, 6 dump trucks

The sound levels for each of these pieces of equipment are listed in Table 12-73.

The total sound pressure level of the equipment in each of the four areas will be: reservoir, 92.3 dBA; ash disposal, 91.3 dBA; evaporative ponds, 88.5 dBA; and power block and cooling tower, 109.9 dBA. The principal contributors to cooling tower and power block construction will be pneumatic wrenches and rock drills. Trucks will also be significant noise sources, largely because of their numbers.

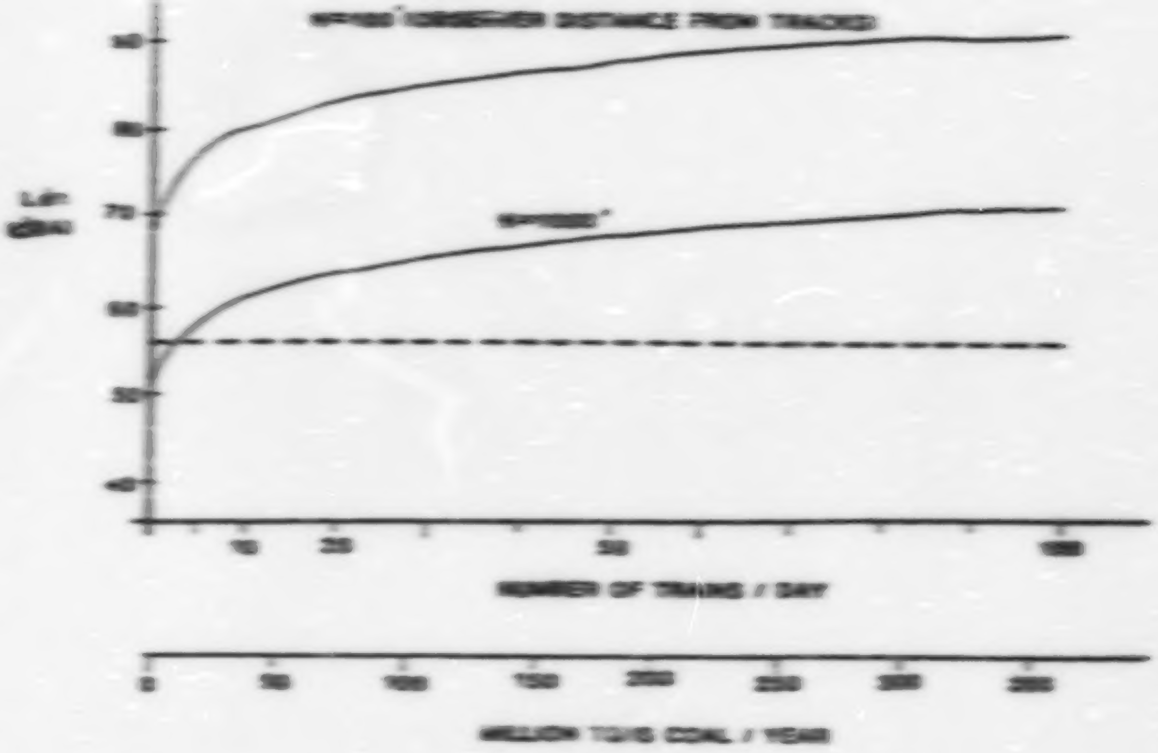

FIGURE 12-15: DAY-NIGHT AVERAGE SOUND LEVEL (Ldn) AS A FUNCTION OF COAL TRAIN FREQUENCY AND COAL TONNAGE

TABLE 12-73: REPRESENTATIVE SOUND LEVEL FOR CONSTRUCTION NOISE SOURCES

Equipment	Sound Level Per Unit (dBA)
Bulldozer	80
Air Compressor	86
Welding Generator	83
Rock Drill	99
Pneumatic Drill	98
Crane	79
Grader	86
Dump Truck	81

dBA = decibels A-weighted

Source: Bolt, Beranek, and Newman. Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances. Cambridge, Mass.: Bolt, Beranek, and Newman, 1971.

Expected noise radiation during plant construction is shown in Figure 12-16. Contours of constant sound level (L_{dn} isopleths) are shown in 5-dB increments from 30 to 70 dBA. The results show that L_{dn} will be greater than 55 dBA within a range of approximately 4,000 feet (over three-quarters of a mile) of the construction areas. This will probably annoy people residing near construction sites as well as the construction workers.

12.8.5 Surface Strip Mining

The principal noise sources during typical surface strip-mining operations will be bulldozers, the dragline, rock drills, blasting, and coal haulers.[1] An assumed typical mining operation is shown in Figure 12-17, which emphasizes the topographic barriers to noise resulting from surface mining.

Sound levels for each of the above sources are given in Table 12-74. The 50-foot high piles of overburden will effectively block most sound radiation. For the typical mining geometry shown in Figure 12-17, the spoils piles will attenuate radiated levels by about 15 dBA in the northern and southern quadrants.

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[1] The noise impact of blasting depends on size and depth of charge, acoustic properties of soil, and presence of sound attenuating barriers, thus is highly variable.

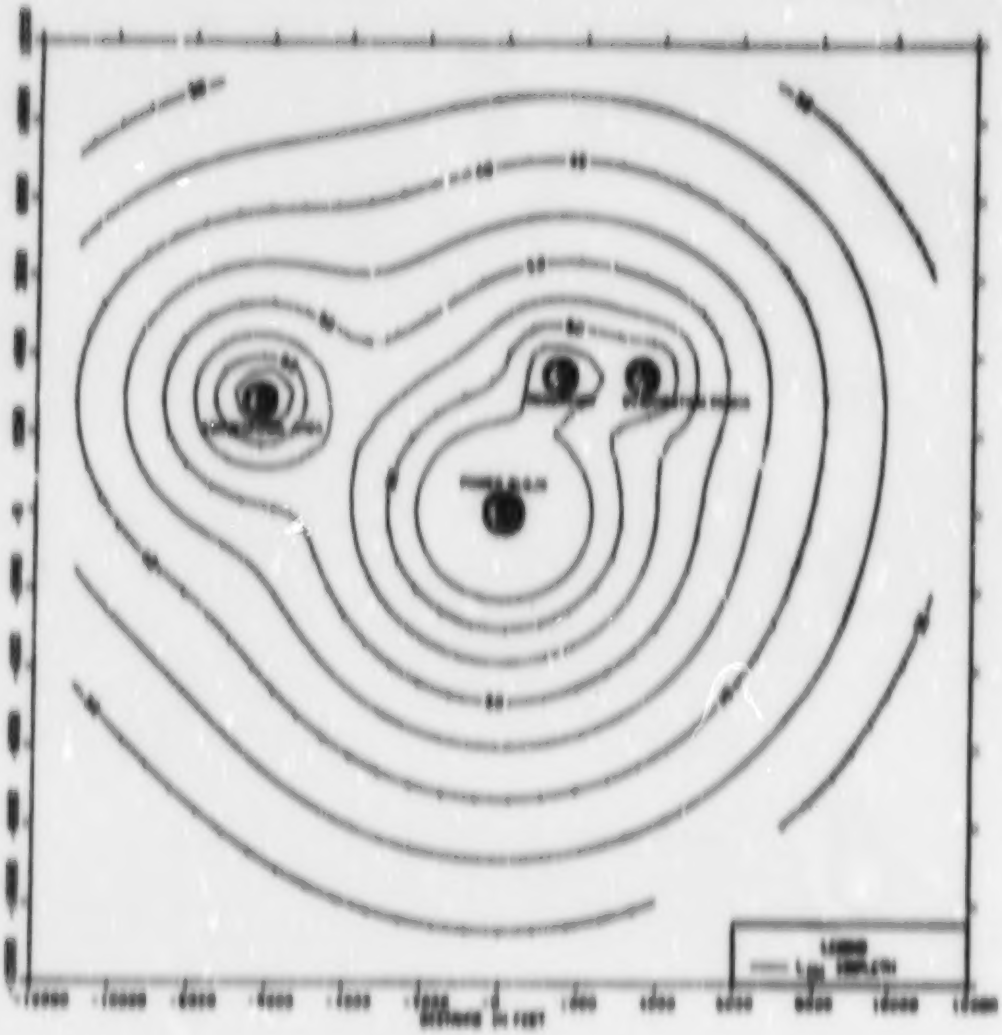

FIGURE 12-16: RADIATED NOISE FOR TYPICAL POWER PLANT CONSTRUCTION

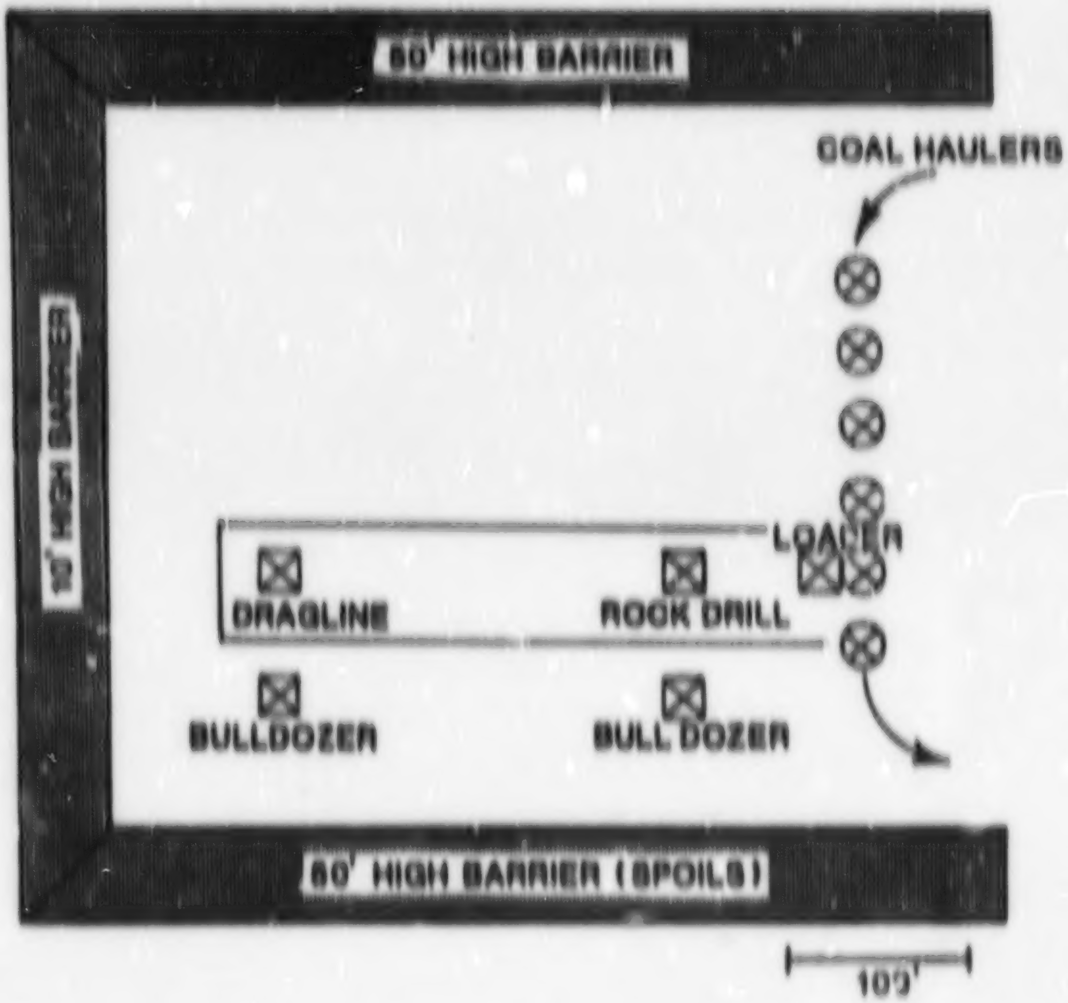

FIGURE 12-17: TYPICAL COAL MINE SCENARIO

TABLE 12-74: REPRESENTATIVE SOUND LEVEL FOR MINING NOISE SOURCES

Equipment	Sound Level Per Unit (dBA)
Dragline	68
Bulldozer	82
Rock Drill	72
Loader	72
Coal Haulers	7

dBA = decibels A-weighted

Source: Battelle Memorial Institute, Columbus Laboratories. Detailed Environmental Analysis Concerning a Proposed Coal Gasification Plant for Transwestern Coal Gasification Co., Pacific Coal Gasification Co., and Western Gasification Co., and the Expansion of a Strip Mine Operation Near Burnham, N.M. Owned and Operated by Utah International, Inc. Columbus, Ohio: Battelle Columbus Laboratories, 1973.

Predicted radiation noise levels, in the form of L_{dn} contours, are shown in Figure 12-18 for the typical surface mining operation.

Haulers will be the principal noise source. Their L_{dn} will be less than 55 dBA in all directions for distances greater than 2,000 feet and will have less impact than the noise levels predicted for power plant construction and operation.

12.8.6 Plant Operation

Principal noise sources for a typical coal-fired power plant will include the cooling towers, pulverizer, bulldozers on the coal pile, coal car shakers, and railroad car switching. Representative data for these equipments are listed in Table 12-75. Attenuations due to the power block and the coal pile were included in the noise level prediction calculations.

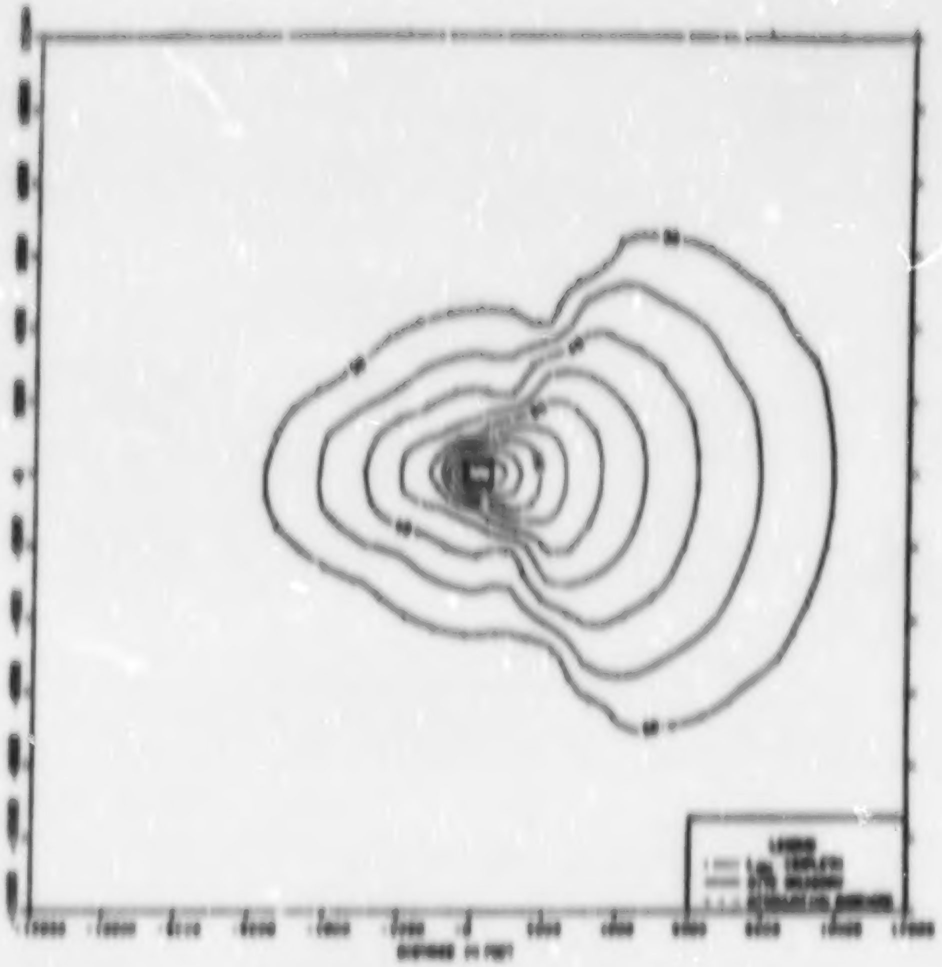

FIGURE 12-18: RADIATED NOISE FOR TYPICAL COAL MINING OPERATION

TABLE 12-75: REPRESENTATIVE SOUND LEVEL FOR COAL-FIRED POWER PLANT NOISE SOURCES

Equipment	Sound Level Per Unit (dBA)
Cooling Towers[a]	104
Pulverizer	104
Bulldozers[b] (270 horsepower)	80
Car Switching[c] (50% duty)	92
Coal Car Shakers	101

dBA = decibels A-weighted

[a] Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

[b] Bolt, Beranek, and Newman. Noise from Construction Equipment and Operations, Building Equipment and Home Appliances. Cambridge, Mass.: Bolt, Beranek, and Newman, 1971.

[c] Swing, Jack W., and Donald B. Pies. Assessment of Noise Environments Around Railroad Operations, Report No. WCR 73-5. El Segundo, Calif.: Wyle Laboratories, 1973.

The predicted radiated noise levels for plant operation are shown in Figure 12-19. L_{dn} levels of 55 dBA will extend to about 1 mile from the plant. Thus, some community annoyance should be expected out to this distance. L_{dn} levels of 45 dBA will extend to about 1.7 miles from the plant. The plant noise will be noticeable to about this range.

12.8.7 Summary

The rail shipment of coal by unit trains in the West will be a major contributor of noise impacts from energy development. This will be especially significant because of the length of rail line and thus the number of people impacted. (Some estimates are discussed in Section 12.7.) At a more local level, energy conversion facility construction and operation will create annoying noise levels up to 1 mile away from a plant site. Surface mining will be less of a noise problem, with annoyance levels extending less than .5 mile from the mine, largely because of spoils piles and other barriers. The distribution of mining and facility noise impacts will depend entirely on the locational distribution of energy development in the West.

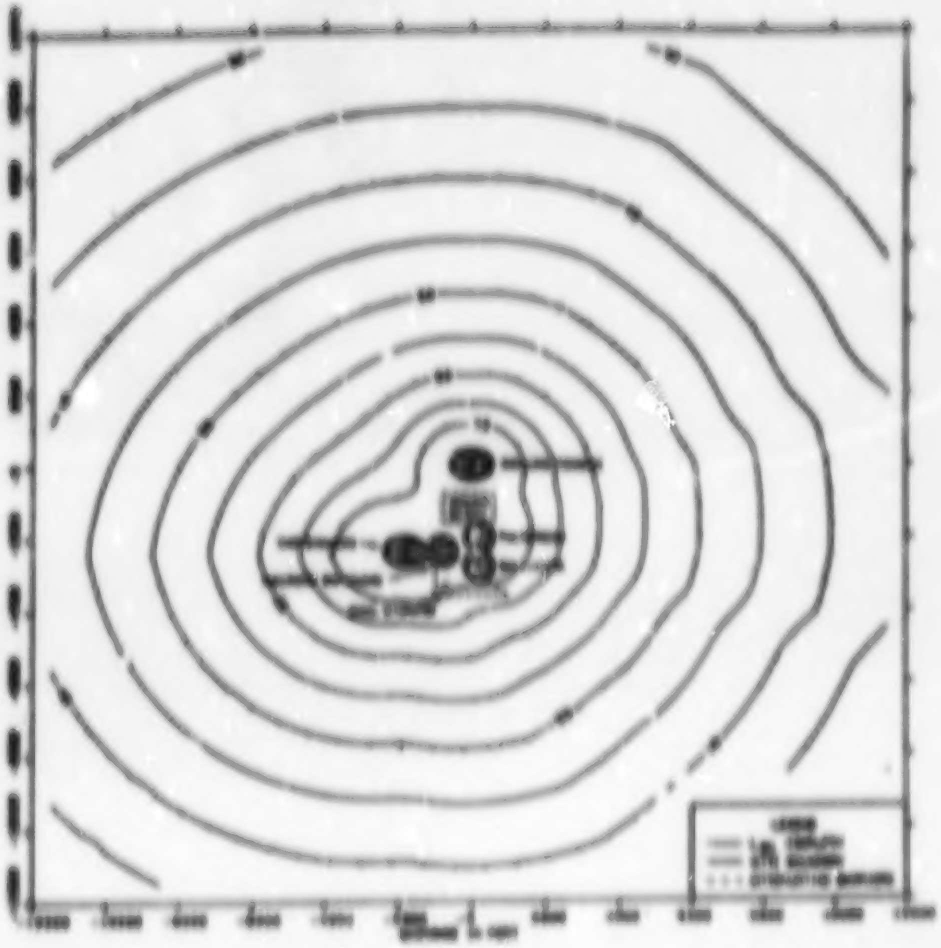

FIGURE 12-19: RADIATED NOISE FOR TYPICAL POWER PLANT OPERATION

12.9 AESTHETIC IMPACTS

12.9.1 Introduction

Since aesthetic impacts are subjective, they vary among individuals. For example, personal experiences and priorities basically determine the values that different people place on visual qualities. Although aesthetic characteristics are a quality-of-life consideration, the latter are generally associated with more tangible social and economic aspects of life, such as satisfaction with personal income, housing, and employment. However, both kinds of concerns are identifiable only through personal responses. Especially for aesthetics, technical measures and aggregate tabulations of data must give way in large part to subjective reactions.

Our categories of aesthetic impacts include land, air, sounds, water, biota, and man-made objects (Table 12-76); the overall aesthetic character of a place is comprised of all these factors. Site-specific identification is required because variation from place to place is an essential aspect of aesthetics. Impacts and their causes in each of the six categories are discussed in the following sections.

12.9.2 Land

Strip mining will be the source of most of the aesthetic land impacts throughout the West. The texture of overburden piles is usually coarse but not distinctive, and uniform from pile to pile. The color varies depending on the location but seems most often to be a uniform grey, a color that quite often is not consistent with the surrounding surface. Long ridges without variation are the major relief and topographic characteristics of overburden spoils.

State strip-mining reclamation legislation typically contains provisions requiring land to be returned to its original grade; in many cases in the West, this will improve the aesthetic nature of strip-mined topography. In some cases, aesthetics could be improved by regrading efforts that add distinctive new contours to the land and that allow the development of vegetation which was not natural to the area before mining took place. Success of reclamation will vary, but the arid Four Corners area and local areas such as southeastern Montana (where aquifers lie within or near coal seams) will be less easily restored.

12.9.3 Air

Air-related aesthetic impacts are likely no matter where conversion facilities are located in the West. Long-range visibility as a physical air impact is discussed in Section 12.2. The long-range visibility and clean air now enjoyed in most areas

TABLE 12-76: CATEGORIES OF AESTHETIC IMPACTS

Category	Contribution Factors
Land	Surface Texture and Color Relief and Topographic Character
Air	Odor Visibility
Sounds	Background Intermittent
Water	Clarity and Rate of Movement Shoreline Appearance Odor and Floating Material
Biota	Domestic Animals, Kind and Quantity Wild Animals Diversity and Density of Vegetation Unique Species
Man-made Objects	Density Skyline Alteration Conspicuousness Overall Impression Isolation Unique Composition

Source: adapted from Battelle Memorial Institute, Columbus Laboratories. *Final Environmental Evaluation System for Water Resource Planning*. Report to U.S., Department of the Interior, Bureau of Reclamation, Contract No. 14-06-D-7182. Washington, D.C.: Bureau of Reclamation, 1972, pp. 59-66; Grossman, Martin W. *Quality of Life Indicators: A Review of State-of-the-Art and Guidelines Derived to Assist in Developing Environmental Indicators*. Springfield, Va.: National Technical Information Service, 1972; Water Resources Research Center of the Thirteen Western States, Technical Committee. *Water Resources Planning, Social Goals and Indicators: Methodological Development and Empirical Test*. Logan, Utah: Utah State University, Utah Water Research Laboratory, 1974.

of the western states are highly valued, and the deterioration of visibility, whether physically measurable or not, is widely considered a significant aesthetic impact.[1] A single visible plume in an otherwise clear sky can result in a negative response from some people.

Odors are frequently associated with air pollutants, such as sulfur dioxide and oxides of nitrogen. However, there are other causes of odors such as trace pollutants and various hydrocarbons (HC). Any noticeable odor will usually be perceived as an aesthetic impact. Ground-level sources, such as fugitive HC emissions will be a major source of this impact.

12.9.4 Noise

Noise impacts are detailed in Section 12.8. Most authors place noise in the overall category of aesthetic impacts even though criteria have been established for noise levels. The reason for this is that noise criteria have been set for occupational hazards but not for public nuisance. Noises which will not damage hearing can still substantially disrupt the quality of life in a community and, therefore, be aesthetically displeasing. As indicated in Section 12.7 and 12.8, people living near busy rail lines in the West will be increasingly impacted by noise.

12.9.5 Water

The clarity and rate of movement of water are highly valued aesthetic qualities. Water consumption for energy development will probably increase turbidity and lower flow rates, thereby reducing the rate of water movement in many streams. Some ecological impacts of this have been noted as secondary impacts in some of the local scenarios discussed.

Shoreline appearance can be affected by increased nutrient levels in streams which generate shoreline algae, by reduced stream flows or lake levels which expose previously submerged areas, or by increased turbidity which may settle out to change the color of shore areas. Odors in streams can be caused by increased biological or chemical oxygen demand, excess chlorine or fluorine, and/or various trace materials and pollutants. Odors can be perceived as aesthetically unpleasant even if levels are well within water quality standards. Floating material is almost never considered to be aesthetically pleasing. Garbage, beverage cans, sewage, and oil slicks, all associated with increased local population, are very apparent aesthetic impacts and generate substantial negative public responses.

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[1] Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity," Audubon Magazine, Vol. 78 (Spring 1976), 64-80.

12.9.6 Biota

The aesthetic impact of domestic animals is mixed and often depends on the number of animals. Most people perceive a single stallion or a mare and colt as being aesthetically pleasing, but the dust and odor generated by a herd of horses is often considered a negative aesthetic impact. Wild animals are usually perceived more favorably and considered to be an asset to an area. A negative impact of energy facilities will occur, then, when a development reduces the number of wild animals either due to consumption of grazing land or the presence of increased population. A valued feature of most public parks is the diversity and well-being of both vegetation and wildlife.

Increased vegetation is almost always a welcome aesthetic addition in and near urban areas. Reclamation efforts at strip mines near towns are critical in this regard. The presence of unique species of plants or animals is a highly valued aesthetic benefit, and reductions in endangered species due to energy development would be a major impact.

12.9.7 Man-Made Objects

The density of buildings or other man-made objects is usually aesthetically important, and a vast expanse of buildings, railroad cars, drill holes, or other evidence of human presence is aesthetically objectionable to many people. Skyline alteration can be an important impact because of the long distance from which a structure on the skyline can be observed. Tall smokestacks or transmission lines are often the most objectionable of these features, especially in the rural West where man-made features are relatively few. However, even right-of-way clearings for buried pipelines may produce an objectionable skyline alteration.

Conspicuousness is related to skyline alteration, but a facility may be conspicuous without altering the skyline. Color, architectural design, and location relative to tall natural features are important here, and facilities designed to conform to the surroundings wherever possible are often aesthetic benefits rather than costs. This will be least likely in the Northern Great Plains where the local topography is flat.

12.9.8 Summary

The composite effect of facilities and surroundings can be pleasing or objectionable without any of the above categories being affected. Architectural compatability between new facilities and surroundings are important here, as well as mundane items such as fences and signs. There will be pressure to retain untouched land features or locations with unique compositions or appearances such as southern Utah.

Isolation as an aesthetic value also varies among individuals. For natives of the western states, isolation is often sought and valued, and the increase in population and addition of new facilities will be accurately perceived as a reduction in their isolation. Methods of measuring aesthetic values and impacts are not well-advanced but do tend to rely on extensive survey-based information.

12.10 SUMMARY OF SIGNIFICANT REGIONAL IMPACTS

12.10.1 Air Impacts

With 80-percent efficient scrubbers on power plants, the sulfur dioxide (SO_2) residual densities (tons of SO_2 residuals per square mile of area) for counties in the oil shale area of Colorado will approach those of Denver, Colorado. Thus, pollution problems similar to those in Denver may occur in those counties. The highest levels of coal conversion in the Northern Great Plains would also result in residual densities close to those in Denver. The possibility that plume impaction will generate high ambient concentrations in local areas also exists, but plume impaction alone is a local impact and will not result in widespread pollution.

If scrubbers are not used, a number of areas will experience residual densities comparable to Denver. Densities in the oil shale area of western Colorado would exceed Denver's. Substantial areawide pollution would probably result. On this basis, scrubbers will probably be needed to assure that air quality in the Western states is maintained.

The emissions densities for the six states suggest that sulfates are not likely to be a problem on a statewide basis.[1] However, on a local basis summer air mass trajectories (following cold air fronts) would probably transport pollutants from the Powder River Basin to Denver and pre-frontal trajectories would probably transport pollutants from the San Juan Basin to Denver. However, the air masses from the San Juan Basin must traverse the Rockies before reaching Denver and would probably lose most pollutants in the process.

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[1] Based on assumption that 1-3 percent of sulfur dioxide (SO_2) will convert to sulfates. Some studies indicate substantially higher conversion of SO_2 to sulfates, from 5-20 percent per hour for oil-fired power plants. U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere, Review of Research Related to Sulfates in the Atmosphere, Committee Print. Washington, D.C.: Government Printing Office, 1976.

12.10.2 Water Impacts

Water requirements for energy facilities postulated for the Upper Colorado River Basin for the year 2000 may be as much as 38-71 percent of the unused water in the Basin. (This could be reduced to between 28 and 58 percent if water minimization techniques are used.) Water requirements for energy facilities in the Upper Missouri River Basin will only be about 10 percent of the water not now being used.

There are serious legal and jurisdictional barriers to acquiring water in both the Upper Colorado and Upper Missouri River Basins. Competition for water in the Upper Colorado River Basin (UCRB) will become more intense during the time frame of the postulated energy development. Similarly, barriers exist to the use of water from the Yellowstone River which appear to prohibit certain energy uses and restrict others. Acquiring water from other streams in the Upper Missouri River Basin (UMRB) would add substantial costs to some energy developments in the Powder River Coal Basin.

For the quantities of water required for UCRB developments, likely shortages could produce substantial impacts. Large-scale energy development in the Basin will intensify existing problems of surface water availability so that some potential users may be denied water supplies. Consumption of this water could reduce the dilution of salts in the Colorado River and increase dissolved solids concentrations. However, if this water were consumed by agriculture, salt loading in the river would be aggravated to an even greater degree since return flows from irrigation will add salts to the river.

Groundwater resources in the UCRB are likely to be adversely affected by mine dewatering, withdrawals for municipal or rural domestic needs, and possibly by the disposal of sewage and industrial effluents. Groundwater reductions from dewatering and withdrawals will result in springs and seeps drying up. Effluents from energy facilities will be contained in lined holding ponds but leaks or seepage could create ground- or surface-water impacts.

Water needs for the postulated energy facilities in the UMRB could eliminate the navigation season on the Lower Missouri for as many as 11 of the next 75 years assuming 10 million acre-feet of withdrawals for energy use. Groundwater resources from the Madison aquifer may be used to supplement the water needs of energy facilities in the UMRB. This may adversely affect the availability of groundwater for municipal needs and necessitate the drilling of deeper wells.

12.10.3 Social, Economic and Political Impacts

By 2000, energy resource development in the study area will result in population increases of between 750,000 and 1,250,000 in the region. Providing facilities and services for these people will create problems for most of the governments involved, but since the increases are due to energy developments which involve substantial capital investments, the tax base available to provide services will, on the average, be adequate. However, serious problems of intergovernmental cooperation might occur because the jurisdiction receiving the tax income will not necessarily be the one required to provide services.

Land consumed for energy facilities will not be a large fraction of the total land available in the region, but in resource-rich counties and subregions, as much as 10 percent of land area will be occupied by energy facilities. This change in land use will affect both the economy and lifestyle of the present population.

The availability of skilled personnel to construct and operate energy facilities will not generally be a problem because the demands for most critical skills are well below 10 percent of the national supply. However, shortages may exist by 1985 in three skill categories: mining engineers, chemical engineers, and boilermakers. To satisfy the demand for these skills, training programs must be initiated, particularly for boilermakers.

By 1985, unemployment could be reduced by nearly 13 percent due to western energy development, and railroads and railroad equipment industries will each experience 15 percent increases in output. Bottlenecks in the development of other particular subsectors of the economy may result from western energy development. Steel foundries will need to increase production by nearly 10 percent, but within that sub-category only a few foundries can handle the large pressure vessels and other equipment needed for energy facilities. Nearly $1.3 billion in new investments in support industries will be required to satisfy the demands of western energy development in 1982. Railroads will need nearly $420 million or 32 percent of that amount.

Geographically, four cities can be taken as examples of substantial impacts due to western energy development but for different reasons. These cities are: Birmingham, Alabama and Pittsburgh, Pennsylvania for steel and railroad equipment; and Salt Lake City, Utah and Duluth, Minnesota for mining-related industries. Industries supporting the electric utilities will also experience 5-10 percent increases in business.

12.10.4 Ecological Impacts

Regional increases in human population will contribute to habitat degradation, particularly in recreational areas. These effects will probably be greatest in national forests, parks, and wilderness areas in close proximity to resource development, such as the Black Hills and White River National Forests.

For arid parts of the West, reclamation will be difficult, particularly in areas that are presently being overgrazed. In areas of greater rainfall or less stress from livestock, reclamation can be accomplished, although native biological communities will generally not be restored.

Based on residuals generated by energy developments, widespread damage to biota from air pollutants appears unlikely. However, damage in localized areas near energy facilities may occur.

Aquatic biota will be affected due to reductions in stream flow and reservoir construction. Decreases in aquatic impacts will be difficult to achieve if the anticipated water uses are realized.

12.10.5 Health Impacts

Maintenance of the low levels of criteria pollutants achieved in this scenario make health effects due to these pollutants unlikely. However, a health hazard may exist if conversion rates of SO_2 to sulfate approach 5 percent per hour. Under these circumstances, health problems such as asthma, bronchitis, and respiration diseases would be locally aggravated. Health effects may occur due to trace materials and carcinogenic hydrocarbons existing in coal or generated in processing facilities. Not enough is known about the quantities or effects of these materials to determine the magnitude of impacts at this time.

12.10.6 Transportation Impacts

As noted above, increases in railway traffic may result in substantial noise impacts, inconveniences at grade crossings, and local restrictions of wildlife movements. By the year 2000, as many as 80 unit trains per day will travel the route from the Powder River Basin to Chicago, with comparable traffic between other areas. For the Nominal case in the year 2000, 17 slurry pipelines are postulated to originate in the Powder River Basin, and these will require approximately 112,000 acre-feet of water per year. The number of coal gondolas and engines for unit trains will be significant and will require substantial increases in equipment production.

12.10.7 Aesthetic Impacts

The most significant aesthetic impacts will result from changes in the appearance of strip-mined land, changes in long-range visibility and odor of air due to air pollutants, reductions in clarity and flow of water, and changes in skyline appearance. Increases in population and building densities will also create aesthetic impacts.

12.10.8 Noise Impacts

Noise generated by coal unit trains can have a major impact on the people living within 1 mile of the rights-of-way. Approximately 1.1 million people along the route from Powder River Basin to Chicago will be affected adversely, and substantial re-routing of railroads will be necessary to reduce this impact. Other noise impacts will only affect people close to energy facilities.